THE

JOURNAL OF GEOLOGY

NOVEMBER–DECEMBER, 1897

THE GEOLOGIC RELATIONS OF THE MARTINEZ GROUP OF CALIFORNIA AT THE TYPICAL LOCALITY.

THE term "Martinez Group" was first used by W. M. Gabb in his classification of the Cretaceous of California,[1] the group of strata provisionally so designated being considered by him as standing between the Chico of his Cretaceous A and his Tejon or Cretaceous B. The Martinez was said to be of small geographical extent and to bear such a relation to the Chico that future investigation might show it to be a part of that group. About sixty species were listed by Gabb from the group, most of them having been collected near the town of Martinez, in Contra Costa county.

For a number of years after the publication of the second volume of Gabb's work on the palæontology of California, the Martinez group was scarcely mentioned in geological literature, probably because, as described by him, it was not well understood. However as the Cretaceous B or Tejon came to be generally considered as Eocene the importance of the group, as a possible connecting link between the Chico-Cretaceous and the Tejon-Eocene, became evident.

[1] See Rep. Geol. Surv. of Cal. Palæontology, Vol. II, p. 13 of Preface. Gabb divided his Californian Cretaceous into a lower division, A, including the Shasta, Chico, and Martinez (?), and an upper division, B, or the Tejon. His Cretaceous B is now generally regarded as Eocene.

In a recent publication[1] by Mr. T. W. Stanton the fauna and stratigraphy of a number of the most important of Gabb's Martinez localities have been clearly discussed and a complete reorganization of the hitherto heterogeneous group effected. Mr. Stanton has shown the Martinez of Gabb to consist of two parts, one characteristic Cretaceous and inseparable from the Chico group, the other being more closely related faunally and stratigraphically to the Tejon-Eocene than to the Chico. The upper portion was therefore placed with the Tejon and designated as Lower Tejon. As a possible modification of his classification Mr. Stanton states that, "if more detailed field work makes it desirable to retain the name (Martinez) at all, it should be restricted to the Eocene (upper) portion . . . ."

In the following discussion the name Martinez is applied to that portion of Gabb's Martinez group which remains, after the removal of the Chico-Cretaceous element. The writer's statements are based on observations, extending over a period of several years, made in the typical region for the group, viz., that adjacent to the town of Martinez.

In the hills to the southwest of Martinez strata of unquestioned Chico age, containing a characteristic fauna, occur over a considerable area. In a fine outcrop of compact, bluish sandstone occurring on the west side of Alhambra Valley, and near the top of the Chico, the writer found an abundance of fossils, characteristic of this group, which are listed in the table below, under Locality No. 1. From this point to the east and west the structure of the strata is anticlinal, showing an apparently conformable series up as far as the Miocene on each side.

From the standpoint of stratigraphy, one would hardly be disposed to find fault with Gabb's conception of the Martinez, since in this, the typical locality, the Chico, Martinez, and Tejon, *appear* everywhere to be conformable, while numerous complications of the stratigraphy have still farther increased the difficulty of separating these three groups on stratigraphic grounds.

[1] The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast 17th Ann. Rep. U. S. Geol. Survey, 1895-6.

Lithologically there are some differences between the Martinez and the adjoining formations, the most important of which are the slightly different aspect of its sandstones and the frequent presence in them of considerable quantities of glauconite. The sandstones are often grayish, differing from the yellowish or bluish rocks of the Chico and the massive white to dull red Tejon sandstones. In many places the Martinez contains large quantities of glauconite disseminated evenly through the sandstones in rounded grains of considerable size. Glauconite does not seem to occur at all in the Chico but may possibly be found toward the base of the true Tejon. The truly glauconitic rocks belong principally to the Martinez.

While the group shows little which would serve to separate it stratigraphically or lithologically from the over and underlying formations, its fauna, on which Gabb based his classification, contains numerous elements throwing light on its geologic relations. Between the Chico-Cretaceous and the Miocene there are two distinct faunas present, viz., the Martinez (in part) and Tejon of Gabb, or the Lower and Upper Tejon of Mr. Stanton. As other criteria failed to separate satisfactorily the Chico, Martinez, and Tejon, extensive fossil collections were made by the writer at all possible points. A series of rich localities running across the strike from the Chico to the Tejon furnished the sequence of faunas as shown in the table on pages 770 and 771.

An examination of these lists shows that the lower Martinez beds, as stated by Mr. Stanton, have a fauna distinct from that of the Chico, and that, while the two sets of rocks may seem to be conformable, an unconformity, as yet unobserved, probably exists. There are no species common to localities 1 and 2 excepting *Dentalium Cooperi* which ranges up into the Tejon and appears to be identical with a form occurring in the lowest Miocene. Other localities furnishing a few imperfect fossils are known in beds perhaps somewhat lower down than Locality No. 2 but as yet no distinct overlapping of the two faunas has been discovered.

Locality No. 3, higher up in the group, furnishes a fauna of

TABLE SHOWING CHANGES OF FAUNA FROM CHICO TO TEJON.[1]

	Chico	Martinez	Tejon
Locality No. 1.—Typical Chico.			
1 *Corbula cultriformis* Gabb	*		
2 *Meekia sella* Gabb	*		
3 *Meekia navis* Gabb	*		
4 *Meretrix arata* or *fragilis* Gabb	*		
5 *Mytilus quadratus* Gabb	*		
6 *Mytilus pauperculus* Gabb	*		
7 *Nucula truncata* Gabb	*	*	*
8 *Pecten martinezensis* Gabb	*		
9 *Pectunculus Veatchi* Gabb	*		
10 *Tellina Hoffmanniana* Gabb	*		
11 *Tellina aequalis* Gabb (?)	*		
12 *Venus varians* Gabb	*		
13 *Cinulia obliqua* Gabb	*		
14 *Cylindrites brevis* Gabb (?)	*		
15 *Dentalium Cooperi* Gabb	*	*	*
16 *Gyrodes expansa* Gabb	*		
17 *Perissolax brevirostris* Gabb n. var.	*		
18 *Pugnellus hamulus* Gabb	*		
19 *Solarium inornatum* Gabb	*		
20 *Helicoceras vermicularis* Gabb.	*		
21 Sharks' teeth 2 sp.	*		
22 Teleost fish scale			
Locality No. 2.—Lower Martinez.			
1 *Flabellum Remondianum* Gabb		*	*
2 *Placosmilia* n. sp		*	
3 *Schizaster* (?) n. sp		*	
4 *Arca* n. sp		*	
5 *Cardium Cooperi* Gabb		*	†
6 *Cucullaea Mathewsoni* Gabb		*	
7 *Leda Gabbi* Conr		*	*
8 *Lucina* sp		*	
9 *Meretrix* sp		*	
10 *Modiola* n. sp		*	
11 *Pholadomya nasuta* Gabb		*	
12 *Tapes quadrata* Gabb (*aff.*)		*	*
13 *Tellina* n. sp		*	
14 *Actaeon* (?) n. sp		*	
15 *Cylichna costata* Gabb		†	*
16 *Dentalium Cooperi* Gabb	*	*	*
17 *Discohelix* n. sp		*	
18 *Fusus* n. sp. (*a*)		*	
19 *Fusus* n. sp (*b*)		*	
20 Indet. nov		*	
21 *Neptunea mucronata* Gabb		*	
22 *Perissolax Blakei* Conr. n. var.		*	
23 *Siphonalia lineata* Stanton		*	
24 *Turritella* sp		*	
25 *Urosyca caudata* Gabb		*	
26 *Urosyca* n. sp		*	
27 *Xenophora* n. sp		*	
28 Glauconite			
29 Foraminifera			
Locality No. 3.—Upper Martinez.			
1 *Arca* n. sp		*	
2 *Cardium Cooperi* Gabb		*	†
3 *Cucullaea Mathewsoni* Gabb		*	
4 *Leda Gabbi* Conr		*	*
5 *Modiola ornata* Gabb		†	*
6 *Pholadomya nasuta* Gabb		*	
7 *Solen* n. sp		*	
8 *Tellina* (?) *undulifera* Gabb		*	
9 *Brachysphingus liratus* Gabb		*	
10 *Bullinula* (?) n. sp		*	
11 *Dentalium Cooperi* Gabb	*	*	
12 *Fusus* n. sp		*	
13 *Heteroterma Gabbi* Stanton		*	
14 *Perissolax Blakei* Conr. n. var.		*	
15 *Siphonalia lineata* Stanton		*	
16 *Strepsidura packecoensis*, Stanton		*	
17 *Turritella infragranulata* Gb.		*	
18 *Urosyca caudata* Gabb		*	
Locality No. 4.—Near Upper Limit of Martinez.			
1 Nummuloid		*	
2 *Schizaster* (?) n. sp		*	
3 *Cardium Cooperi* Gabb		*	†
4 *Cardita Hornii* Gabb		†	*
5 *Modiola* n. sp		*	
6 *Solen* n. sp		*	
7 *Tellina Hornii* Gabb		†	*
8 *Tellina* n. sp		*	
9 *Thracia* (?) n. sp		*	
10 *Ampullina striata* Gabb (*conf.*)		*	
11 *Dentalium stramineum* Gabb	*	*	*
12 *Ficopsis* sp. (near *Remondi*)		*	*
13 *Megistostoma striata* Gabb		†	*
14 *Morio* sp. (*tuberculatus?*)		†	*
15 *Solarium* n. sp		*	
16 *Tritonium* n. sp		*	
17 *Tritonium* (?) n. sp		*	
18 *Turris* n. sp		*	
19 *Turritella* n. sp. (?)		*	

[1] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

TABLE.—*Continued.*[1]

	Chico	Martinez	Tejon
LOCALITY NO. 5.—TEJON, A SHORT DISTANCE ABOVE LOCALITY NO. 4.			
1 *Trochosmilia striata* Gabb....			*
2 *Cardium Breweri* Gabb.....			*
3 *Cardium Cooperi* Gabb		*	†
4 *Cardita Hornii* Gabb.....		†	*
5 *Meretrix Hornii* Gabb.....			*
6 *Meretrix uvasana* Conr.....			*
7 *Modiola ornata* Gabb.....		†	*
8 *Nucula truncata* Gabb.....	*	*	*
9 *Pectunculus sagittatus* Gabb..			*
10 *Amauropsis alveata* Gabb....			*
11 *Cylichna costata* Gabb.....		†	*
12 *Conus Remondi* Gabb.....			*
13 *Dentalium Cooperi* Gabb....	*	*	*
14 *Ficopsis Remondi* Gabb.....			*
15 *Ficopsis* sp. (near *Remondi*)...		*	*
16 *Morio* sp. (*tuberculatus*).....		†	*
17 *Perissolax Blakei* Conr. Typ. var.....			*
18 *Rimella canalifera* Gabb.....			*
19 *Turritella uvasana* Conr.....			*
20 *Oliverato californica* Cooper ..			*

the same type as that of No. 2 but containing some forms as *Tellina* (?) *undulifera*, *Turritella infragranulata*, and *Brachysphingus liratus*, not present in the lower beds. One minute specimen of the characteristic Tejon form, *Modiola ornata*, was obtained at this horizon.

At Locality No. 4, near the upper limit of the Martinez, about one third of the fauna is composed of species known from the Tejon. Of these forms *Dentalium stramineum* is a long-lived species ranging from Chico to Tejon. *Cardium Cooperi*, though known from Tejon beds, is not a common or characteristic fossil of that group, while it ranges through the Martinez and is one of its most characteristic species. The *Cardita* belongs to the Tejon species described as *Hornii* by Gabb but may be a new variety. *Megistostoma striata*, *Tellina Hornii* and the *Morio* seem to be typical Tejon forms and are not found below the uppermost beds of the Martinez. The *Ficopsis* sp. is a form known from the Upper Martinez and Lower Tejon. Imperfect specimens of a foraminifer related to *Nummulites* are abundant at this locality. Though the fauna at this horizon is certainly closely related to that of the true Tejon, only three good species are common or characteristic forms in that group.

[1] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

At Locality 5, a short distance (less than 100 feet) above No. 4, fossils of the well-marked fauna to which Gabb gave the name Tejon are found in abundance, *Cardium Cooperi* being the only really characteristic Martinez species associated with them. No localities showing more gradation between the Martinez and Tejon faunas than those here discussed have so far been discovered by the writer.

Numerous other collections made between Localities 2 and 3 and between 3 and 4 furnished gradations from one to the other, with some additional species not mentioned in the foregoing lists.

In the following table there are placed together all of the species known to the writer from the strata between the Chico and the true Tejon near Martinez, along with those which have been collected elsewhere by Mr. Stanton, in beds of the same age. A study of this list shows clearly that the fauna is a unit, and that it is quite distinct from both the Chico and the Tejon, though it grades to some extent into the latter.

The existence between the Chico and the Tejon of a fauna not belonging clearly to either group, was evidently not unknown to Gabb, and this fauna formed the real basis of his Martinez. Unfortunately the involved stratigraphy led him or his collectors into the error of supposing that certain Chico forms belonged in the same horizon with Martinez species, while the first error led to a second, viz., the belief that, since Chico forms were present in his Martinez fauna, the whole group might be found later to represent a subdivision of the Chico. As has been shown in the comparison of faunas, there can be little doubt that the Chico group is widely separated from what is here called Martinez.

In considering the relations of the Martinez to the Tejon, it might be well to determine first what was intended in the original definition of the Tejon group and what it really is. The name was proposed by Gabb on *palæontological grounds* for a set of rocks, supposed by him to be Cretaceous, but now generally regarded as Eocene, "most extensively developed in the vicinity

THE FAUNA OF THE MARTINEZ GROUP WITH GEOLOGICAL RANGE OF THE SPECIES.[1]

	Chico	Martinez	Tejon
1 Foraminifera Nummuloid		*	
2 Foraminifera 3 sp. Indet.....		*	
3 *Flabellum Remondianum* Gabb.....		*	*
4 *Placosmilia* n. sp.....		*	
5 *Schizaster* (?) n. sp.....		*	
6 *Terebratula tejonensis* Stanton		*	
7 *Arca* n. sp.....		*	
8 *Cardita Hornii* Gabb.....		†	*
9 *Cardium Cooperi* Gabb.....		*	†
10 *Crassatella unioides* Stanton ..		*	
11 *Cucullæa Mathewsoni* Gabb...		*	
12 *Leda alæformis* Gabb.....		*	
13 *Leda Gabbi* Conr.....		*	*
14 *Lima multiradiata* Gabb.....		*	
15 *Lucina Turneri* Stanton.....		*	
16 *Meretrix* sp.....		*	
17 *Modiola* n. sp.....		*	
18 *Modiola ornata* Gabb.....		†	*
19 *Nucula truncata* Gabb.....	*	*	*
20 *Pectunculus Veatchi* var. *major* Stanton.....		*	
21 *Pholadomya nasuta* Gabb.....		*	
22 *Plicatula ostreiformis* Stanton		*	
23 *Solen* n. sp.....		*	
24 *Tapes quadrata* Gabb (*aff.*) ...		*	*
25 *Tellina* n. sp.....		*	
26 *Tellina Hornii* Gabb		*	*
27 *Tellina* (?) *undulifera* Gabb..		*	
28 *Teredo* (?).....			
29 *Thracia* (?) n. sp.....		*	
30 *Actæon* (?) n. sp.....		*	
31 *Ampullina striata* Gabb (*conf.*)		*	
32 *Brachysphingus liratus* Gabb.		*	
33 *Bullinula* (?) n. sp.....		*	
34 *Cylichna costata* Gabb.....		†	*
35 *Dentalium Cooperi* Gabb.....	*	*	*
36 *Dentalium stramineum* Gabb	*	*	*
37 *Discohelix* n. sp.....		*	
38 *Ficopsis* sp (near *Remondi*)...		*	*
39 *Fusus* n. sp (*a*)		*	
40 *Fusus* n. sp. (*b*)		*	
41 *Heteroterma Gabbi* Stanton...		*	
42 *Heteroterma striata* Stanton..		*	
43 *Heteroterma trochoidea* Gabb.		(?)	
44 Indet. nov.....		*	
45 *Lunatia Hornii* Gabb.		†	*
46 *Megistostoma striata* Gabb...		†	*
47 *Morio* sp. *tuberculatus?*.....		†	*
48 *Natica* sp.....			
49 *Neptunea mucronta* Gabb....		*	
50 *Perissolax Blakei* Conr. nov. var.....		*	
51 *Siphonalia lineata* Stanton...		*	
52 *Solarium* n. sp		*	
53 *Stripsidura pachecoensis* Stanton.....		*	
54 *Tritonium* n. sp. (*a*)		*	
55 *Tritonium* (?) n. sp. (*b*).....		*	
56 *Turbinella crassitesta* Gabb ..		*	
57 *Turritella infragranulata* Gabb		*	
58 *Turritella pachecoensis* Stanton		*	
59 *Turritella* n. sp. (?).....			
60 *Turris* n. sp.....		*	
61 *Urosyca candata* Gabb.....		*	
62 *Urosyca* n. sp		*	
63 *Xenophora* n. sp.....		*	
64 Crustacean remains, brachyuran.....		*	
65 Crustacean remains, macruran		*	
66 *Serpula*			

of Fort Tejon and about Martinez." It was stated[2] to contain "a large and highly characteristic series of fossils, the larger part peculiar to itself, while a considerable percentage is found

[1] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

[2] Rep. Geol. Surv. Cal. Palæontology, Vol. II, p. 13 of Preface.

extending below into the next group, and several species still farther down into the Chico group." Since Gabb's work was published the Tejon has been recognized at numerous points on the Pacific coast, outside the limits of its distribution as known to him, and has always been found to contain an easily recognized fauna, of which a number of the most common and characteristic forms are found in the list of species from locality No. 5. As may be seen in the last quotation, the true relation of the Martinez to the Tejon, as shown by the partial mingling of species, was not unknown to Gabb.

In the vicinity of the town of Martinez, the Martinez and Tejon groups form an apparently conformable series between two and three thousand feet in thickness and about equally divided between the two. The faunas, though overlapping, are in the main quite distinct and no great difficulty has been experienced by the writer in separating the groups on this basis. While some intermingling of species exists, it is not greater than we should expect to find in adjoining groups or periods. It should also be observed that the beds with a Tejon-like Martinez fauna and those containing an assemblage of characteristic Tejon forms are comparatively close together. The change from one fauna to the other may possibly have taken place in a short time by migration, but we cannot assert positively as yet that the apparent conformity of the beds is a real one, sedimentation may have been interrupted between the times of deposition of the two groups. It is at any rate quite clear that the two sets of strata, or two faunas, while belonging perhaps to the same series, represent different periods in the geological history of California, periods quite as distinct, so far as faunal evidence is concerned, as the Miocene and Pliocene, or the Pliocene and Quaternary. The upper division of this series has already, on the grounds of its characteristic fauna, been named the Tejon. To a mixed group of rocks, to which the fauna here called the Martinez gave individuality, the name Martinez group was applied by Gabb. It seems desirable, after having cut out the Chico portion of Gabb's Martinez which was probably not the one on which he based the group,

to apply the name used by him to the distinct fauna or group which remains. As to the nomenclature of the supposedly conformable series, including the Martinez and Tejon, it seems best to apply to it for the present the term Martinez-Tejon series, though future convenience may demand a special series name. To apply the name Tejon to the whole series would be to modify considerably the meaning of this term as used originally, and would have besides the fault of taking the name from a smaller division to apply it to a larger, leaving the first to be virtually renamed.

In conclusion, the group under consideration might be characterized as follows: The Martinez group, comprising in the typical locality between one and two thousand feet of sandstones, shales, and glauconitic sands, forms the lower part of a presumably conformable series, the upper portion of which is formed by the Tejon. It contains a known fauna of over sixty species, of which the greater portion is peculiar to itself. A number of its species range up into the Tejon and a very few long-lived forms are known to occur also in the Chico. Since the Martinez and Chico are faunally only distantly related it is probable that an unconformity exists between them. Though satisfactory correlation of Californian formations with the subdivisions of the standard geological scale can be accomplished only when the local scale is fully worked out, we may, for the present at least, accept Mr. Stanton's correlation of the Martinez with a portion of the Eocene.

JOHN C. MERRIAM.

BERKELEY, CALIFORNIA.

Contact Metamorphism.— The endomorphic changes wrought by the granite intrusions are relatively slight. Thus the biotite-gneiss and hornblende-gneiss southwest of Lake Wakawan have the same mineralogical composition at the contact as they have a quarter of a mile away from it along the strike. On Spindle Point, gneisses of like nature show the only exomorphic change discovered throughout the whole terrane of the Lake Winnipiseogee gneiss. Yet even this is a doubtful case, since the only evidence is the presence of some sillimanite needles and a few garnets in the schist near the granite. Again, the interbedded biotite-gneiss, muscovite-biotite-gneiss, and actinolite-gneiss, at the outlet of Little Squam Lake, are practically unaffected by the granite. The same is true of the large biotite-gneiss-inclusion on the north side of Beech Hill, as well as of the whole contact-line of the Montalban group.

The schists on Saddle Hill exhibit the best metamorphic belt which appears in the Winnipiseogee area. Specimens of the country-rock were taken at localities from one to eight hundred feet from the contact, and in all of them the country-rock proves to be a typical muscovite-biotite-schist with accessory sillimanite in long needles. Inside that zone toward the granite, however, a pronounced metamorphic aureole encloses phases of the terrane which represent important modifications of the schist. One of them, some eighty feet from the contact, is a hornfels largely made up of zoisite and andalusite (?) with quartz and magnetite. Another, four feet from the granite, is a compact mica-schist richly charged with garnets; while within five inches of the contact this garnetiferous schist has absorbed a large amount of orthoclase and plagioclase which seem to have been derived from the neighboring granite.

The Ashuelot area is even more nearly devoid of distinct zones of contact-alteration. Several suites of specimens were taken across the marginal belt of schists at several different localities, but in none of them was a definite alteration of mineral content observable, as one goes toward the igneous rock. While the Coös schists are highly garnetiferous at the contact, they are often just as metamorphic in habit a mile or more from the granite. Interlaminated actinolite-schists are abundant among the common mica-schists of the area. They show no change at the contact. The Bethlehem gneiss is often garnetiferous, and in some slides the garnets are seen to be larger and more idiomorphic near the granite than away from it. Apart from this fact, one would not suspect from an inspection of the marginal alterations that the porphyritic granite was once an igneous body intruded in these same rocks in a molten state.

Finally, it would be difficult to point to any particular part of the Main area as exhibiting metamorphic phases in the schistose country-rock of the porphyritic granite which could not have been produced before the granite was erupted. One hundred and fifty feet from the great Greenfield sheet a typical quartz-garnet-hornfels can be found, but from that rock to the granite one passes over the typical biotite-muscovite-schist of the region. The latter itself may be garnetiferous. It does not, however, differ from similar phases of the ferruginous rocks several miles from the contact. North of Henniker there outcrops another hornfels at a contact with a prophyritic granite apophysis and about 50 feet from the molar contact. It is a compact aggregate of quartz and garnet with a large admixture of a colorless pyroxene and a little accessory plagioclase and muscovite. Notwithstanding this kind of association, these and other examples cannot as yet with safety be considered as contact phases, nor do they afford positive evidence of an eruptive origin for the porphyritic granite.

The small amount of exomorphic change in the contact-belt is that which might be expected from the conditions of the eruptions. It is well known that, other things being equal, acidic

igneous rocks are less likely to be altered by intrusive masses than are the more basic rocks. In the same way sedimentary rocks are in general more susceptible to contact metamorphism than the crystalline chists or than igneous rocks.[1] Pohlig noted important differential effects of the trachyte in the Siebengebirge. Fragments of gneiss enclosed in the eruptive rock were relatively unchanged as compared with inclusions of clay-slate in which andalusite and other metamorphic minerals were developed.[2] Lehmann has described granulite inclusions in the granite of Markersdorf which he found to be entirely unchanged by the granite.[3] No student of contact-belts needs, however, to be reminded that in them there is pronounced selective metamorphism depending upon the nature of the rocks invaded. Those which have advanced furthest in the direction of mineralogical stability will usually be the rocks which are least altered. If, then, there had been regional metamorphism of the country-rock before a given intrusion occurred, such terranes will tend to be without distinct zones of alteration. Such is the case with the New Hampshire rocks. In the sequel the chief evidence for this conclusion will be given, but we can anticipate somewhat by stating the fact that the same series of schists which are cut by the porphyritic granite are just as thoroughly crystalline many miles from the porphyritic granite as they are in its immediate vicinity. Moreover, they attained this crystalline character in the process of mountain-building and not by any kind of local thermo metamorphism induced by underlying areas of the porphyritic granite.[4] The eminent schistosity of these rocks was anterior to the granitic intrusion, and it is an effect concomitant with the recrystallization. Thus it was a series of terranes already regionally metamorphosed that were cut by the porphyritic granite. They had reached a state of approximate mineralogical equilibrium and but little rearrangement of the constituent elements was possible by mere contact action.

[1] Cf. HUDLESTON, Address Pres. Geol. Soc., 1894; Q. J. Geol. Soc., p. 121.
[2] Tschermak's Mitth., 1880–1, p. 353.
[3] Untersuch. über die Entsteh., der altkryst. Schiefergesteine, 1884, p. 7.
[4] Cf. BARROW, Q. J. Geol. Soc., 1893, p. 352.

Moreover, at Fitzwilliam, where the inclusions of the neighboring biotite-gneiss are extremely well exposed, there does not seem to be the slightest change in the horses. Yet there can be no doubt that the porphyritic granite is here distinctly eruptive in the gneiss. In the same way, the ancient granitite described on the west and northwest of the village of Antrim has produced no material alteration in the composition of the schist inclusions, for in that feature they are identical with their parent terrane for several miles from the contact.

It seems reasonable, then, to conclude from the brief account of exomorphic contact-phenomena just given that they do not invalidate the argument for the porphyritic granite's being eruptive. It means that the conditions were not such as to permit of the development of the well-marked metamorphic aureoles which one might expect in invaded terranes composed of relatively unaltered rocks.

Endomorphic changes.— More often than not where the actual contact between the porphyrictic granite and the older formations appears, there is practically little change either in the composition or grain of the granite. This fact is characteristic of apophyses as well as of the main body. In the Winnipiseogee and Main areas particularly, the feldspar phenocrysts and their matrix are remarkably persistent in the size of individual minerals. The reader will remember that a broad band of the porphyritic granite with rare phenocrysts appears on the western side of the Ashuelot area, and again that, on the eastern side, there is evidence of fine-graining in the Bethlehem gneiss-contact which can hardly be explained except as belonging to a chilled phase of the igneous rock. It is true, however, that this phenomenon is, on the whole, rather the exception than the rule in the different areas. We cannot but think that the invaded schists must have been at a high temperature themselves when the granite was intruded. Witness the widespread zones of passage between the two. The great coarseness of the matrix shows that the granite was long in crystallizing and in that process would naturally lose much heat to the surrounding rocks.

Thus the latter could not in the final stage of consolidation cause a serious differential cooling in the marginal part of the granitic magma. That there was some influence exerted upon the igneous rock is indisputable. Almost universally thin sections of the contact-zone exhibit a very marked granophyric intergrowth of the quartz and feldspar of the matrix. This micrographic development is quite independent of that noted as common about the phenocrysts, and is quantitatively much superior in value to the latter. The occurrence of the graphic structure in the matrix is usually restricted to the contact-zone of not more than a few inches or feet in width. It is noteworthy, however, that in parts of the Ashuelot area where there are evidences of some crushing, this structure is found in various parts of the coarse matrix, though far from a contact. It doubtless originated as a result of rearrangement during the period of stress which the rock has here undergone.

The origin of the foliation in the porphyritic granite.—It is now well established that gneisses may belong to three classes which in the words of Gregory[1] may be named metapyrigen-gneisses, clastic-gneisses, and fluxion-gneisses. The first kind is produced by the pressure-metamorphism of igneous rocks, the second by the complete alteration of sediments. The third division has its origin in molten rock-magmas which have undergone "fluxional movements anterior to complete consolidation in a mass not perfectly homogeneous."[2] The porphyritic granite of New Hampshire owes its foliated structure to the same cause as that of fluxion-gneisses. In short, this porphyritic gneiss is a porphyritic granite with a flow-structure. The parallelism among the constituents was assumed when the rock was not yet fully crystallized out and cannot thus be referred to any metamorphic result of mountain-building acting on an already solidified mass. It is a primary structure. Since this fact is not as yet demonstrated in what has been said, and since we are dealing with a

[1] Q. J. Geol. Soc., 1894, p. 266.

[2] T. G. Bonney, Some Notes on Gneiss, Geol. Mag., 1894, p. 118. Cf. Hill and Bonney, Q. J. Geol. Soc., 1892, p. 137.

great terrane characterized everywhere by this foliation which has been the subject of serious misapprehension among early investigators in the state, we shall go into some detail to establish this position.

It was not until the next generation after von Buch [1] described flow-structure in lavas that the phenomenon was studied with reference to the origin of gneisses. Scrope [2] in 1840 and Darwin [3] in 1844, closely followed by Naumann,[4] first laid emphasis on the truth that "dragging movements" on a cooling granitic magma may lead to the formation of gneiss. Since that time, a host of observations have confirmed their idea so completely that it is now possible to frame the most important criteria which ought to be applied to a problematical case, and, if satisfied, should enforce belief in the gneissic structure of that particular instance being of fluxional origin. It is proposed to consider briefly these criteria with respect to their validity and to their relation to our particular problem.

1. Since the fluxion-structure is due to differential stress, we should expect some parts of a mass, to display a greater excellence of the foliation than others. There will be zones of relatively rapid movement and zones of more static conditions; at least during the geological movement of final consolidation. Thus, we may expect to find transitions from trendless granite to well-foliated granite or gneiss.[5] We have already seen how abundantly this change is exemplified in all the areas of the porphyritic granite. Both of the State Surveys noted this relation between the massive and foliated phases.[6] The earlier one seized upon the former as indicating simply a granite, the second

[1] Geognost. Beobacht. auf Reisen durch Deutschland und Italien, 1809, II, p. 209.

[2] Trans. Geol. Soc., 2d ser., II, p. 228.

[3] Geological Observations, etc., 1st ed., 1844, ch. iii.

[4] Neu. Jahrb., 1847, p. 297. Q. J. Geol. Soc., Notices of Memoirs, p. 1.

[5] MICHEL LÉVY, Bull. Soc. Geol. de France, 1878–9, p. 852. MCMAHON, The Gneissose-Granite of the Himalayas. Geol. Mag., 1887, p. 214. *Ibid.*, 1888, p. 63. HARKER and MARR, The Shap Granite, etc. Q. J. Geol. Soc., 1891, XLVII, p. 284 EMERSON, Bull. Geol. Soc. Am., I, 1890, p. 559.

[6] Note, Geol. of New Hampshire, Vol. II, p. 99.

survey regarded the non-foliated parts as fused parts of a series of altered sediments.

2. The parallel structure ought to be best assumed along the contact, because there the essential condition of an appropriate viscidity will be assumed within a zone which has a dominant trend. Where the interaction effects of more than two cooling surfaces meet, as they do in a mass of considerable breadth, there is a tendency towards the obliteration of parallelism induced in any one zone of chilling at a plane of contact. Convection currents will further complicate the flow-structure and to a greater extent in the hotter core of an intrusive mass than in the chilled zone. For these reasons parallelism among the constituent minerals should be most clearly exhibited along the boundaries where the structure-planes of the igneous mass will accord in direction with the plane of contact. The central area may either lose any incipient foliation or show sudden irregular changes of strike and dip of fluxional planes which do exist. In other words, wherever else it may appear, the fluxional structure is to be looked for chiefly at the margins.[1]

[1] BRÖGGER (Die Silurischen Etagen 2 und 3; Kristiania, 1882, pp. 325, 326), describes the endomorphic zone of contact of his granitic and syenitic eruptives as possessing a parallel structure "wodurch gestreifte Gesteine, bisweilen wie echte krystallinische Schiefer aussehen. It is parallel to the irregular boundaries of the igneous rocks.

MCMAHON, Note on the Foliation of the Lizard Gabbro; Geol. Mag., 1887, p. 76.

BARROIS states that in the granulites of Morbihan the parallelism is most perfect when the contact-line is in the strike of the enclosing strata. In such parallel contacts, the granulite is apt to change to a "granulite porphyroïde, à grands éléments, alignés fluidalement." In "contacts perpendiculaires" the rock has an aplitic phase in which the crystalline constituents have regular geometric forms. He considers that such differences in the intruded granite depend on the country-rock as an agent chemically inactive but "diversement conducteur de la chaleur et de la pression." Sur les modifications endomorphes des massifs granulitiques du Morbihan; Comptes Rendus, CVI, 1888, p. 428.

GEIKIE, A., The History of Volcanic Action during the Tertiary Period in the British Isles; Trans. Roy. Soc. Edin., 1888, p. 37.

BARLOW, On the Contact of the Huronian and Laurentian Rocks North of Lake Huron, Am. Geol., VI, 1890, p. 22.

SMITH, W. H. C., Ann. Rep. Geo. Surv. Canada, 1890-1, map.

GREGORY, J. W., The Waldensian Gneisses and their Place in the Cottian

The reader will remember how often this principle was illustrated in our detailed account of contact-phenomena. It undoubtedly explained the greater perfection of the foliation in the long and narrow Winnipiseogee area than that in the broadly eliptical Ashuelot area or Main area. At the Bennington reservoir in the large size of the feldspar phenocrysts and their definite orientation with respect to the adjacent contact we have a good example of what characterizes the endomorphic zone of the Main area throughout the eastern contact as mapped. Within the zone the structure is much less determinate. Again, on Sandwich Mountain the porphyritic granite in and about the "permeation-area" described above, is largely granitic with the exception of those parts which display the fluxional habit about the horses. We are not without suggestion that the sudden changes of dip and strike within the cores of the igneous masses are largely the result of convection acting with massive pressure in the still viscid rock-body. Two miles from Weirs, on the highway to Meredith village, several outcrops appear in a clear field some three hundred yards to the right of the road. At one of these, a well-marked anticlinal arrangement can be observed in typical porphyritic granite. This structure is not part of a general system of parallel folds, nor of folds with any recognizable relation to the behavior of solid rock acted upon by lateral force. It is rather to be correlated with the irregular flow-structure assumed in the internal parts of many rhyolites; the well-known "felsites" of eastern Massachusetts furnish a good example.[1]

3. An analogous appearance will tend to characterize the margins between the intrusive rock and any foreign bodies which

Sequence; Q. J. Geol. Soc., 1894, p. 249. On page 265 the author says of the foliation in these Alpine gneisses that it is "a contact-fluxion, and has no connection with the dynamo-metamorphism of the district. This marginal orientation also occurs on a microscopic scale. Mr. C. L. Whittle has described good examples in the contacts of the Connecticut Triassic lavas.

BONNEY, T. G., Some Notes on Gneiss; Geol. Mag., 1894, p. 118.

[1]Cf. MEHNER, "Fluctuationstructur" described in certain of "die schiefrigen Porphyren" of Westphalia; Tsch. Mitth., 1877, p. 177.

are caught up from the surrounding terranes.[1] In many cases, however, it is due not only to differential cooling, but to the pulling of the horses along in the direction of the migrating viscid magna. Such is the case with the examples of the circumferential arrangement of feldspars noted on Sandwich Mountain, on Saddle Hill, and in the Fitzwilliam area, and elsewhere.

4. Many observers have described the orientation of horses parallel to the margins of contact in cases where the inclusions have distinct elongated form.[2] The latter condition is usually furnished in the case of fragments derived from a country-rock with plane-parallel-structure. Consequently, we can understand this very general marginal arrangement described in all of the principal areas.[3]

5. The greater the heterogeneity among the constituents of the igneous body at the time of proximate consolidation, the more pronounced will be the flow-structure.[4] As suggested by Bonney,[1] horses may be melted up and thus give local variations in the mineralogical constitution of the igneous body. "Banding" is sometimes produced by the imperfect mixing of more

[1] LAWSON, The Geology of the Rainy Lake Region; Ann. Rep. Geol. Surv. Canada, 1887-8, F, 137-138. BARLOW, op. cit., p. 29. DAKYNS and TEALL, On the Plutonic Rocks of Garabal Hill and Meall Breac; Q. J. Geol. Soc., 1892, p. 106. KOTO, B., The Archæan Formation of the Abukuma Plateau; Jour. Coll. Sci. Imp. Univ., Tokio, 1893, p. 288. GREGORY, Q. J. Geol. Soc. 1894, p. 242.

[2] DUROCHER, Mém. de la Soc. Géol. de France, 2e sér., t. VI. See his descriptions of several gneiss-granite contacts in Scandinavia; LEHMANN, Untersuchungen über die Entstehung der altkryst. Schiefergesteine. Bonn, 1884, pp. 16, 21; GEIKIE, A., op. cit., p. 39; GRANT, U. S., Field observations on certain granitic areas in northeastern Minnesota; 20th Ann. Rep. Minn. Surv., 1891, p. 40.

[3] Cf. EMERSON, Bull. Geol. Soc. Am., I, 1890, p. 559.

[4] Geol. Mag., 1894, p. 119. Cf. BONNEY, *ibid.*, 1894, p. 118. C. CHELIUS has recently described a stage leading to the complete fusion of enclosed masses, which is of interest. In this case granite cuts diorite and includes so many lenses of the latter in parallel arrangement as to simulate a "grobflaseriger gneiss." Notizbl. d. Ver. f. Erdk. Darmstadt, IV, Folge, 14 Heft, 3-8, 1893. Ref. in Neu Jahrb., 1895, p. 72.

J. J. SEDERHOLM speaks of "Schlieren" rich in mica and garnets in the "druckschieferiger Granit" of Finland. They are taken to represent remnants of schist-inclusions which have been dynamically metamorphosed. Om Börggrunden i Södra Finland, 1893. Ref. in Neu. Jahrb., 1895, p. 335.

than one phase of a magma.[1] It is conceivable that it might be locally brought about by the pulling out of basic segregations in a plutonic rock by mechanical force operating during or after complete consolidation.

On the road along the north shore of Wickwas pond a striking phase of the porphyritic granite was found which had been discovered before but never in such perfect development. It forms a strongly schistose mass a few inches thick which lies parallel to the foliation of the normal rock. Composed largely of brown biotite with here and there a large feldspar phenocryst, it is very different in appearance. With the biotite large apatites and considerable masses of titanite and magnetite make up the groundmass. This band had much the appearance of a shear-zone, like that described in the crystallines of the Malvern Hills.[2] But the microscope discloses no strong evidences of crushing in the feldspars which are clearly original or primary in their nature. Now there are plenty of cases on record where biotite segregations in granitic rocks grow to large size. Those at Graniteville, Missouri, vary from a few inches to five feet or more in diameter.[3] It may be that this and similar local bands in the rock in question are due to the tailing out of such segregations before the final solidification of the whole rock had set in. The resulting bands would thus be parallel to neighboring structure-planes and take their place as primary elements in a fluxional mass.

But the most favorable chance for the exhibition of a parallel structure over large areas would be given in cases where there is more than one generation of minerals; *i. e.*, in porphyritic rocks. Such, indeed, has been the character of most of the plutonic rocks where extensive flow-structure has been described. The large size of the phenocrysts of the porphyritic granite is one of the chief conditions leading to this peculiar and widespread foliation. Possessed of large growth before the final magmatic crystallization set in, each feldspar phenocryst was, as it were,

[1] HARKER and MARR, Q. J. Geol. Soc., 1891, p. 283; A. GEIKIE and TEALL, *ibid.*, 1894, p. 656.

[2] Q. J. Geol. Soc., 1889, p. 477.

[3] Geol. Surv. Missouri, Ann. Rep., VIII, 1894, p. 154.

of the nature of a foreign body embedded in the matrix. Thus, it would behave in the same manner as the truly exotic inclusion and a conspicuous alignment would result. It was observed in the field that, as a rule, the greater the dimensions of the phenocrysts, the more clearly was the structure displayed.

It is clear that the porphyritic granite with its elongate feldspar phenocrysts abundantly fulfills this criterion. In fact, the study of it suggests that plutonic rocks would more generally show a flow-structure were their constituents more varied in shape and relative size from the usual forms.

Quite rarely a broad banding is observable which is the result of the juxtaposition of layers containing different proportions of the phenocrysts.[1]

6. The negative criterion is valuable and in this New Hampshire case is most conclusive. If it can be shown that mountain-building could not induce the parallel structure in any secondary fashion, *i. e.*, by the pressure-metamorphism of consolidated, igneous or sedimentary rocks, we can fairly assume that the only other recognized cause has been operative. The evidence necessary therefore is threefold.

First, it may be derived from the study of foreign inclusions. The schistosity of the horses in all the observed localities where they occur within the porphyritic granite was evidently produced before the existence of that rock in its present state of crystallization. In practically all cases where comparison was possible, the excellence of this structure in any one inclusion was reflected in its parent-terrane. As the one varied from massive to schistose with a high degree of fissility, so did the other. Now the perfection of the schistosity was found to be irrespective of the attitude of the horses, *i. e.*, whether they were in parallel arrangement or not. Callaway used the correlative of this principle as an aid in determining the nature of the foliated granites of Northern Donegal.[2] He finds in them inclusions of massive diorites. His conclusion is, that on any theory of a

[1] Cf. G. H. WILLIAMS, Bull. U. S. Geol. Surv., No. 28, p. 26.

[2] READE, Origin of Mountain Ranges, p. 139.

mechanical origin for the foliation, it would be "hard to explain the escape of the diorite inclusions from the same influence." But if the intrusion of the porphyritic granite followed the period of plication and metamorphism, we should expect it to follow commonly the structural planes of the preëxisting schists.[1] Again referring to our detailed description of contacts in the three large areas, it will be seen how commonly this is the case. The intrusions are batholitic in their nature. They entered the overlying rocks by melting[2] their way through the axial zones of flexures. It is for this reason that the general distribution of these granite bodies is along the strike of terranes in this part of New Hampshire. The equivalence of strike and dip in the region in the narrow part of the "Fish-hook" north of Squam Lake between the foliated igneous rock and the adjacent schists is especially conspicuous.[3] Such pronounced apparent conformity is probably owing to an exchanging of the usual batholitic form of intrusion for a sill or sheet-form.

Secondly, the study of apophyses will be of much consequence. If we there see parallelism of the minerals composing the intruded tongue to its walls, no matter what the compass-direction of the apophysis may be, it is evident that the structure cannot be referred to mechanical deformation applied after the cooling of the whole intrusive mass.[4] Scheerer early

[1] See GÜMBEL, op. cit., p. 522, 523, 524. He describes "Lagergranite" intruded into various schists. It is rather remarkable that his "Krystallgranit" of Bavaria does not possess a decided flow-structure. The rock is very similar to the porphyritic granite otherwise. Cf. also LAWSON, Ann. Rep. Geol. Surv. Canada, 1885, CC, p. 73, LEHMANN, op. cit., pp. 10, 23; WILLIAMS, G. H., Proc. A. A. A. S., 1887, XXXVI; Sect. E, p. 225; CALLAWAY, Geol. Mag., 1887, p. 354; LAWSON, Ann. Rep. Geol. Surv. Canada, 1887–8, F, p. 32; DANZIG, Mitth. aus dem Min. Inst. der Univ. Keil Bd. I. heft 1, 1888, p. 66; BARLOW, Am. Geol., VI, 1890, pp. 21–22; HARKER and MARR, op. cit., p. 284; ADAMS, Jour. of Geol., 1893, p. 334: SMITH W. H. C., Bull. Geol. Soc. Am., 1893, p. 338.

[2] From the author's previous statements there is no evidence that melting took place in connection with these intrusions. [ED.

[3] See the map of Hunter's Island by Mr. W. H. C. SMITH, which shows a very remarkable parallelism of the foliation in his "granite gneiss" with the strike of the enclosing schists. Ann. Rep. Geol. Surv. Canada, 1890–1.

[4] LAWSON, The Geology of the Lake of the Woods Region; Ann. Rep. Geol.

described an occurrence of the opposite of this.[1] He determined that the red gneiss of the Erzgebirge is plainly eruptive into the gray gneiss. The apophyses of the former have a distinct parallel arrangement among the constituents. It is, however, not parallel to the walls, but inclined to them. He, hence, concludes that it is due to pressure exerted after the consolidation of the ancient granite.[2] That the apophyses should be as coarsely porphyritic as the main body, is of itself a strong suggestion of the exotic origin of the latter.[3] As we have seen, such is the case with the porphyritic granite, and in many instances, as on Saddle Hill, on Sandwich Mountain, in the Greenfield dike, and at Fitzwilliam, the apophyses have a more or less well-developed foliation, parallel to the walls and transverse to the structure-planes of the schists.

Lastly, while the porphyritic granite shows in certain areas evidence of strain, there is none of that very intense crushing which might be looked for if the foliation were of a mountain-built origin.[4] The signs of pressure in some of the phenocrysts may be due to the shearing set up among them in the tough, but still viscid magma, just on the instant of final consolidation. At the south end of the Ashuelot area we have the most schistose phase of the rock. It has evidently been squeezed to some extent. It is crumpled and even changed to an augen-gneiss whose lenticular feldspars represent the idiomorphic phenocrysts of the original rock.[5] Small faults of a half foot throw were observed in the Winnipiseogee area, just

Surv. Canada, 1885, CC. p. 83, DANZIG, Ueber die eruptive Natur gewisser Gneisse sowie des Granulits im sächsischen Mittelgebirge; Mitth. aus dem min. Inst. der Univ. Kiel. Bd. I, Heft 1, 1888, p. 67. REUSCH, Neu. Jahrb., Beil. Bd, V., Heft 1. 1887, p. 57.

[1] Die Gneisse des sächsischen Erzgebirge; Zeit. d. d. geol. Ges., 1862, pp. 122–123.

[2] Credner attempted to prove that the red gneiss of the Erzgebirge is of sedimentary origin and not eruptive, as held by von Cotta, Scheerer, Stelzner, and others. Zeit. d. d. geol. Ges., 1877, p. 757.

[3] Cf. MCMAHON, Geol. Mag., 1888, p. 63; Q. J. Geol. Soc., 1893, p. 357.

[4] Cf. LAWSON, The Geology of the Rainy Lake Region, Ann. Rep. Geol. Surv. Canada, 1887–8, F, pp. 137–138.

[5] Cf. HAWES, Geol. of N. H., III, p. 214.

north of Wickwas pond. But there is nothing to indicate that any batholite as a whole has undergone any such enormous stresses as have affected the anorthosite of Canada, the protogine of the Alps, or even the gneisses of the Malvern hills.[1] Under the microscope the New Hampshire rock always shows that the essential minerals crystallized in place and that they have only been affected, except locality, by moderate pressures.

From the complete satisfaction of these several criteria one cannot escape the conviction that the foliation of the porphyritic granite has nothing to do with stratification, and has not been caused by the alignment of the constituents in a time of pressure metamorphism acting on a consolidated rock.

The significance of the uniformity of the porphyritic granite and its wide geological distribution.— One of the most striking characteristics of the porphyritic granite is the lithological sameness which pertains to it to a great degree throughout all the areas examined. This property is retained irrespectively of the nature of the rock-terranes which it invades. From the many examples of endomorphic changes induced in plutonic rocks by the melting up of foreign inclusions, we have selected a few which are described in the annexed footnote.[2] In view of this principle,

[1] CALLAWAY, Q. J. Geol. Soc., 1887, p. 525.

[2] Michael Lévy finds that by an endogenous action granulite cutting diabases and diorites is enriched in plagioclase at the contact (Bull. de la Soc. Géol. de France 1882–3, p. 296). Lehmann states that where the granitite of Döbeln is intruded into biotite-bearing rock, it is practically unchanged, but when it cuts in contact with sericitic schists, siricite is an important constituent (Untersuch. über Ent. d. altkryst. Schiefergesteine, Bonn, 1884, p. 19). Again, on classic ground, Lawson determines his Rainy Lake eruptive rock to be a quartzose biotite-granite gneiss where it comes in contact with quartz porphyries, yet the same rock-body cutting the more basic hornblende schists becomes a hornblende syenite with little quartz (Ann. Rep. Geol. Surv. Canada, 1887–8, F, 31). In one of the great batholites of western Massachusetts, Emerson notes three phasal differentiations, a heavy hornblende granite, a hornblende granitite, and a granite proper, all of which he attributes to the melting up of three various sorts of crystalline schists respectively (Bull. Geol. Soc. Am., I, 1890, p. 559). A similar affection of a porphyritic granite by a hornblendic country-rock is found in Chor Mountain, India (Geology of India, 2d ed., by Oldham; Strat. and Struc., p. 43); while quite recently Harker notes a good case of a relatively basic modification of granophyre at its junction with gabbro, and ascribes it mainly to an incorporation of re-fused gabbro (Q. J. Geol. Soc., 1895, p. 134).

it may be asked, why does the porphyritic granite not show more variations of mineral content? To this question we have no conclusive answer. It is possible that the rock which now fills the areas of the porphyritic granite was in general not at a temperature high enough to cause vigorous melting up of the walls, and that the great spaces in the earth-crust now filled by the granite were opened during the passage upward of earlier and hotter parts of the same magna. However this may be, the difficulty remains just as great for any theory of a metamorphic origin for the granite. It is impossible to believe that a rock with such continuity of like characters should have resulted from the alteration of the stratified or schistose rocks in the accompanying terranes of New Hampshire. Although the determinations of relative age among these terranes are as yet necessarily imperfect, we know that the porphyritic granite is in contact with rocks of many different horizons and of very variable composition. From this fact, it seems reasonable to conclude that the porphyritic granite is an exotic eruptive, finding its source of supply elsewhere than in any metamorphic center in immediate connection with the encircling schists. McMahon lays considerable stress on this idea in his argument for an eruptive origin of the Himalayan granites.[1] Lawson, in his study of the Laurentian gneisses, and Barlow, in a similar problem among the ancient rocks north of Lake Huron,[2] refer their "irruptive" masses to a fusion of the granitic floor on which the post-Laurentian rocks were laid. The New Hampshire rock is thus, in respect to its origin, more closely allied to the Himalayan granite than to the gneiss of the Canadian Laurentian.

Coarse veins cutting porphyritic granite.— McMahon and others describe plutonic eruptives intersected by dikes and veins of very similar material to that of which their hosts are composed. Besides the usual evidences of an eruptive origin for the Dalhousie gneissose granite of northern India, McMahon adds a criterion which is certainly without the weight of its associates,

[1] Geol. Mag., 1887, p. 216; Rec. Geol. Surv. India, XVIII, 1885, p. 106.

[2] Bull. Geol. Soc. Am., IV, 1893, p. 331.

but which has been recently used more than once. He states that "the granite contains veins similar to those caused by shrinkage on cooling in granites of admittedly eruptive origin."[1] Emerson makes the principle more definite. Speaking of the largest granitic intrusion in Massachusetts west of the Connecticut River, he says: "The great mass is cut everywhere by a very great number of dikes of a coarse muscovite-granite, which seem to represent later intrusions of the central portions of the mass into shrinkage cracks in the already cooled peripheral portions, and thus to represent more truly its original composition."[2] This seems to be the best interpretation of those coarse dikes cutting the porphyritic granite composed of large individuals of the same minerals that make up that rock. They occur everywhere, though there is a concentration of them along the boundaries. With them are often associated the pegmatite veins of variable mineralogical constitution of aqueo-igneous origin and apparently without direct connection with the underlying magma.[3] On Gun Mountain, on Bear Hill, on the road following the valley of Rixford brook, and in the eastern area near New Hampton Centre, dikelike bodies of the former kind transect the porphyritic granite. Such localities suggest that in this respect also the main granitic mass is eruptive.

The age of the porphyritic granite.—We have seen that the porphyritic granite intrusions were posterior to the stress-period during which the chief metamorphism of the New Hampshire rocks was brought about. The position of the axis of flexure determined largely the shape of the different important areas. Each one is batholitic in its nature. Since the eruptions ceased, no considerable deformation has occurred. In this, all the areas are alike, and from other facts, too, they were without much doubt essentially contemporaneous.

Now, the geologically highest fossiliferous zone within the

[1] Geol. Mag., 1887, p. 216.

[2] Bull. Geol. Soc. Am., 1890, p. 559. Cf. HARKER and MARR, Q. J. Geol. Soc., 1891, p. 284.

[3] Cf. BARLOW, Am. Geol., VI, 1890, p. 29.

mountain-built strata is the well-known one at Bernardston, Mass., some seven miles to the southwest of the Ashuelot area. The first studies of the organic forms enclosed in the limestones at this place referred them to the Helderberg or lower Devonian. More recent determinations now fix the age of the limestones as being at the Hamilton-Chemung stage of the Upper Devonian. They are folded up with quartzites and mica- and hornblende-schists which are intensely metamorphic. The careful field work of Professor Emerson and of the late Professor Dana has shown that these metamorphic rocks are a part of the same terrane which throughout this paper and the survey reports of the New Hampshire survey has been called the "Coös group." As early as 1873, Dana concluded that "the Bernardston, South Vernon, and Northfield beds being of Helderberg age, the Coös group, which is but the northern continuation of the same series, is, if correctly traced out, also Helderberg."[1] Professor C. H. Hitchcock adopted this view, although he disagreed with Dana as to the stratigraphic order of the rocks adjacent to the limestones.[2] Professor Emerson followed with the publication of his results after a painstaking lithological and structural study of the whole area. In this paper he most emphatically states his conviction and advances new proof that Dana's position was the correct one.[3] Two years later Dana reiterated his opinion,[4] and in his last and greatest work clearly shows that it persisted for the rest of his life.[5] Professor Emerson is inclined to place the faults and folds which dislocate the Bernardston rocks in Carboniferous or post-Carboniferous time. He attains this result by combining his observations at Bernardston with those in the more richly fossiliferous localities farther south, in the state of Massachusetts. Thus we may conclude that the porphyritic granite is probably a post-Carboniferous

[1] Am. Jour. Sci. (3), Vol. VI, 1873, p. 349.

[2] Am. Jour. Sci. (3), Vol. XIV, 1877, p. 380.

[3] Am. Jour. Sci. (3), Vol. XL, 1890, pp. 263 and 366; especially p. 366.

[4] *Ibid.* (3), Vol. XLIII, 1892, p. 456.

[5] Manual of Geology, pp. 310, 325.

intrusive and certainly younger than the upper Devonian at any rate.

Posterior to the schists, to the so-called protogines, and to other old eruptives on the one hand, the porphyritic granite is, of course, older than the aplitic and lamprophyric dikes which intersect it. It is also older than the Fitzwilliam granite, the hornblende granite stock of Mount Whiteface, the Franconia breccia,[1] and probably older than the complex stocks of the Waterville area. It is impossible with the facts now in hand to go further in fixing an epoch for these great intrusions. The porphyritic granite may even belong to the Tertiary.

SUMMARY.

Briefly stated, the chief conclusions which have been arrived at in the foregoing pages, are as follows:

1. The so-called "porphyritic gneiss" of New Hampshire is at least in the three most important areas, an eruptive porphyritic granite with a common tendency to develop planes of foliation.

It is not to be regarded as indigenous, that is, as the pure fused product of the surrounding formations — a deep-seated exotic origin must be posited for the granite. The evidences for an igneous instrusive origin include the composition and structure of the rock itself, the study of field-relations, the fluxional nature of the foliation, the uniformity of the rock in all its extent and the prevalence of secondary dikes and veins of injection apparently derived from the same magma. Besides these positive facts, there are also those embodied in what may be termed negative evidence. It includes all those observations that have been made in which the peculiarities of the region and of each intrusion will explain why some of the usual criteria of eruptive origins are not perfectly fulfilled. Chief among them is the fact of small certain and undoubted metamorphic effects at contacts — one which we have seen can be readily understood from the characters of the invaded rocks. Lastly, the contacts at first sight equivocal prove to be intrusive contacts on comparative

[1] Geol. of N. H., Vol. II, p. 257.

evidence. The existence of zones of passage between the porphyritic granite and the schists with which it comes in contact is a fairly common phenomenon in the case of stocks of plainly eruptive material. Such transitions then form no inherent objection to a similar origin in this instance.

2. The intrusions necessarily took place under great depth of strata. The latter were elevated by the last great period of White Mountain flexure and were practically holocrystalline products of the consequent metamorphism before the porphyritic granite was intruded. The subsequent disturbance of the greatest interest to us in this connection is that which caused the porphyritic granite to assume the parallel structure of flowage under differential stress analogous to that of the Himalayan and Alpine central granites. Since that time, the force operating on the terranes has been relatively slight. It has not sufficed to rub out completely, in any part, this initial structure of the porphyritic granite.

3. The molten rock entered the overlying schists in an irregular fashion but in general followed the regional line of strike of the White Mountain district.

4. Various considerations lead us to believe that the three areas of porphyritic granite described are virtually contemporaneous. They are, in every case, post-Devonian in age, — how much younger is unknown. Not being a basal formation, the terrane loses much of its value in an elaboration of the stratigraphic sequence and a reconstruction of the New Hampshire geological scale is necessary.

5. The porphyritic granite adds its testimony to the value of the opinion recently formulated among geologists that a highly important class of gneisses owes its parallel structure to fluxional movement. And it has the other general kind of interest in exemplifying the truth of Barrois' prophecy "que les terrains paléozoiques sont destinés à s'étendre de plus en plus sur les cartes géologiques aux depens des terrains primitifs."

REGINALD ALDWORTH DALY.

HARVARD UNIVERSITY.

SUPPLEMENTARY HYPOTHESIS RESPECTING THE ORIGIN OF THE LOESS OF THE MISSISSIPPI VALLEY.[1]

THE loess problem still remains obstinate. While it has yielded somewhat to progressive research, there is, I think, a nearly universal feeling of dissatisfaction with all theories thus far advanced. The eolian hypothesis appears to be the better supported so far as concerns the chief deposits of China and perhaps some of those of western America, while the aqueous hypothesis seems best supported so far as concerns the deposits of the Mississippi valley and western Europe. It is the judgment of some students that the ultimate solution will lie in the recognition of both hypotheses, but the means of discriminating between the two and of applying the criteria are as yet wanting. The present paper is intended to be a contribution in this direction. It is confined to the loess deposits of the Mississippi valley, but is probably applicable to the loess of western Europe.

The distribution of the loess in the Mississippi valley seems to be very significant in its peculiarities. These may be summed up in two great features.

1. The loess is distributed along the leading valleys. These embrace not only the great valleys, the Missouri and the Mississippi, but some of the subordinate valleys, as the Illinois, the Wabash, and others. The loess is found along the Missouri River from southern Dakota to its mouth; along the Mississippi River from Minnesota to southern Mississippi; along the Illinois and the Wabash from the points of their emergence from the territory of the later glacial sheets to their mouths. Along these valleys the loess is thickest, coarsest and most typical in the bluffs bordering the rivers and grades away into thinness, fineness and non-typical nature as the distance from the rivers

[1] Read before Section E, Am. Asso. Adv. Sci. Aug. 12, 1897.

increases. In some instances the loess mantle rises to the divide and connects with the similar deposit of an adjacent valley, but the law of progressive fineness and thinness still holds. This relationship is such as to create a very strong conviction that the deposit of the loess was in some vital way connected with the great streams of the region.

2. The second significant feature is the distribution of the loess along the border of the former ice-sheet at the stage now known as the Iowan. (Strictly speaking there was more than one stage of loess formation, but for convenience only the main stage will be here discussed.) The elaborate paper of McGee made us familiar some years ago with this relationship in eastern Iowa. The studies of Calvin and his colleagues, Bain, Beyer, and Norton, of the Iowa Survey, of Winchell and Upham of the Minnesota Survey, of Todd of the South Dakota Survey, and of Salisbury, Leverett, Udden, Buell, Hershey, and the writer of the United States Survey, have greatly extended the evidence of this relationship. It has recently been much advanced by the Iowa geologists and by Leverett and Hershey in northwestern Illinois. Next the border of the ice-sheet the loess is thick and typical, but graduates away with increasing distance from the ice border in a manner similar to the graduation away from the river valleys. On the border next the ice there are developed the formations designated by McGee paha, elongated domes of quasi-drumloidal contours which are mantled by loess. This superficial loess graduates downwards into loess of coarser and coarser texture until it often passes into a nucleus of sand. Below this there is often an embossment of till. These pahas seem to be ice border phenomena. Whatever their special mode of formation their distribution seems to connect them in some more or less direct genetic relationship with the ice.

It has been affirmed by several independent observers that the loess graduates into glacial clays and glacial till and this relationship further tends to confirm the association of the loess with glacial action.

It has been shown by the microscopical examinations of

Salisbury that the loess particles are composed in part of feldspars, amphiboles, pyroxenes and other common constituents of the glacial clays. These silicates are decomposable under prolonged weathering, and hence cannot well be supposed to come from residuary clays under the ordinary conditions of the Mississippi valley. The presence of the calcium and magnesium carbonates, independent of the presence of shells, points in the same direction. This inference is strengthened in a peculiar way by observations in the lower Mississippi valley. Above the Lafayette gravels and below the loess there is a stratum of silt which does not habitually contain the characteristic silicate particles of the loess. This stratum has been by most observers associated with the loess, but it is separated from it by a soil horizon as abundantly affirmed by the observations of Salisbury and the writer. On the other hand it graduates more or less freely into the Lafayette sands and gravels. The stratum is, as we interpret it, the last deposit of the Lafayette stage. It is a typical finishing deposit succeeding a fluvial sand and gravel. Now this has special significance in this relationship, in that it shows that in the stage closely preceding the loess deposit, the Mississippi did not lay down silts of the same constitution as the loess. The inference therefore is that the loess is not simply a fluvial silt brought down from the surface of the river basin, nor common wind drift borne into it, but that it had a special origin connected with glacial action which was competent to supply precisely the kind of silt of which the loess is made.

It is hard to resist the force of this argument from the constitution of the loess taken in connection with the two distributive relationships. Jointly they seem to force the conviction that the loess had its origin in some relationship to the ice of the Iowan stage and to the rivers that led away from the ice edge at that time.

But the hypothesis that the loess is simply an outwash of glacial grindings distributed along the river valleys by the glacio-fluvial waters is attended by grave difficulties. This remains true whether the deposition be supposed to have taken

place either in a strictly fluvial fashion, or in a fluvio-lacustrine fashion, or in a true lacustrine fashion, or in an arm of the sea. In the first place, the vertical distribution of the loess cannot easily be explained. The extreme vertical range is not far from a thousand feet. The range within a score of miles is frequently from 500 to 700 feet. The loess sometimes seems to the field observer to have a special fondness for summit heights. It sometimes mantles topography of a pronouncedly rolling type. It does not then appear to be a deposit which once had a level or even a smooth surface out of which the rolling surface has been eroded, but to be a mantle laid down upon a previously undulatory surface. Such a mantle might perchance be laid down from water, but I am not aware that we have any demonstrative deposition of the kind which closely simulates the mantling of the loess in some of the upland territory. To suppose that the Mississippi, Missouri, Illinois, Wabash and lower Ohio rivers were so swollen that they united over their divides and threw down a mantle of fine silt over the southern and western half of Iowa and the southern parts of Illinois, Indiana and Ohio, is a somewhat severe tax upon belief. It is difficult to imagine the conditions which should have maintained such a body of water. This has been so much discussed that I need not dwell upon it. But even if such a body be supposed, it is difficult to imagine how the deposition could have been precisely what we find in the case of the loess. It is futhermore difficult to account for the presence of the land shells which abound in it; for if this great flood had the ice-sheet for its northern border, it is extremely difficult to imagine how it could have been peopled so widely with the terrestrial mollusks.

The limit of the loess does not appear to be a strictly topographic one. It is difficult to bring its border into strict accord with a horizontal plain as required by the lacustrine and marine phases of the hypothesis, or even into a consistent gradient as required by the fluvial phase, without an arbitrary warping of the surface. The spread of the loess in the lower Mississippi valley is more extensive and reaches greater heights on the east

side than on the west side, so far as present knowledge goes. A similar fact seems to be true of the Missouri valley. I think this is generally true, but my observations are not sufficient to justify its unqualified affirmation as a generalization.

There are other difficulties attending the aqueous theory in its simple application, but I need not attempt an exhaustive recitial here as they have received emphasis in the long battle between the eolian and aqueous hypotheses. The foregoing will I trust suffice to show that there is abundant occasion to still cast about for a more satisfactory explanation of the loess puzzle.

The supplementary hypothesis herewith proposed attempts to divide the honors between the aqueous and eolian agencies. It recognizes the tremendous force of the arguments from the distribution and the constitution of the loess in favor of the glacio-fluvial hypothesis, and it adopts that hypothesis as the fundamental explanation of the origin of the Mississippian loess. It assumes the presence of the Iowan ice at the chief stage of loess deposition. It assumes a very low slope of the land and a consequent wide wandering of the glacial waters. It assumes the development of extensive flats over which the silts derived from glacial grinding were spread. It assumes that the glacial waters were subject to great fluctuations; 1° as the result of periods of warm weather in the melting season, and 2° as the result of warm rains, which not only added directly to the volume of water, but forced the rapid melting of the ice. Gilbert has acutely observed that there is no way in which the atmosphere can convey its heat energy to a glacier so effectually as through warm rains.

Let it be imagined, therefore, that the silty waters from the margin of the ice-fields wandered over broad flats and constantly built them up by their sediments, and that at periodical flood stages they extended themselves widely over the plains, while between the flood stages they withdrew to more limited courses.

The territory covered by the maximum extension of the waters would be the zone of accumulation of fluvial loess. It is

not necessary to suppose that the periodic extensions of the floods were destructive of the vegetation over all the flat region. In some portions not only could vegetation persist, but the land mollusks and other animals dependent upon the vegetation could find a temporary retreat from the flood on the taller vegetation that may have prevailed.

After each of the periodical retreats of the water there would be left extensive silt-covered tracts facily exposed to the sweepings of the wind and from these, when dried, dust could be derived in great quantities to be borne away over the adjoining lands and lodged in their vegetation. The material thus derived would be essentially identical with the glacio-fluvial deposition, and thus the hypothesis seeks to account for the glacial element in the constitution of the eolian portion of the loess. The presence of land mollusks in the upland eolian loess finds in this way a ready explanation, while their presence in the lowland loess mingled with aqueous mollusks finds an almost equally obvious elucidation ; for not only would the upland shells be washed into the lowlands, as we observe they are at the present time, but they would periodically invade the lowlands in the intervals between submergence and would be caught and buried there. Occasionally the shells of the lowland and aqueous mollusks would be borne to the uplands by organic agencies, and possibly in rare instances by the severest type of winds, and hence their occasional presence there is not remarkable.

To make this a good working hypothesis it would appear that there must be an accommodation between the breadth and fluctuations of the fluvial deposits and the extent and massiveness of the eolian deposits, for if we suppose the glacial floods to be confined within narrow channels, the sweeping ground of the winds would have been too scant to give origin to the great mantle of silt then attributable to them, for we must remember that in proportion as the river work is narrowed the wind work is expanded. It is obvious that the eolian factor will cut away its own ground if pushed too far.

There is little question that loess-like accumulations are now

taking place on the bluffs adjacent to the Mississippi and Missouri valleys. Observation seems to clearly indicate this. But such accumulations are relatively scant in amount and limited in extent, and it is difficult, if not impossible, to believe that the great loess mantle had its origin from the wind drift of flood plains no more extensive than those of today. It must be constantly borne in mind that the eolian deposits are measured, not by the quantity of silt borne by the winds and lodged on the surface, but by the *difference* between such lodgment and the erosion of the surface. Under most conditions with which we are familiar the erosion is more than a match for the dust accumulations. The conditions must then have been extraordinary which would give a dust deposition sufficient to supply erosion and still leave so large a residuum as the loess mantle implies. The unleached and relatively unweathered nature of the body of the loess is specially in point here. These considerations warn us of the theoretical danger of too greatly circumscribing the fluvial action.

On the other hand, if we attempt to extend the fluvial hypothesis too greatly we fail to leave sufficient feeding ground for the molluscan life and we encounter the topographical and physical difficulties which have been previously urged against the pure aqueous theory. A Janus-faced hypothesis is here offered in the hope that by a judicious reference of a part of the loess to one class of action and a part to the other, a joint explanation may be found to afford a true elucidation of the perplexing formation. At any rate, it has seemed worth while to propose the hypothesis for trial. It will doubtless be extremely difficult to find a line of demarkation between the two classes of deposits. Such attempts as have been made in this line justify this apprehension. This supplementary theory has been in mind for several years and was briefly suggested in my paper on the *Genetic Classification of the Pleistocene Deposits*, presented at the Fifth Session of the International Congress of Geologists at Washington in 1891.[1] An effort has been made

[1] Compte-Rendu of the Fifth Session of the International Congress of Geologists, Washington, 1891, p. 192.

by some of my colleagues and by myself to find criteria of discrimination between aqueous and eolian loess. While individual types of both deposits are not difficult to find, a criterion or a series of criteria of general applicability which shall distinguish the two and assign to each its appropriate part is yet wanting.

Richtofen in his classic work on China urged as the explanation of the great Chinese loess an eolian hypothesis supplemented by a fluvio-lacustrine hypothesis. He insisted that the original and chief loess deposits were formed by dust blown from the great arid plateaus and lodged on the more fertile plains of China, and that from these primary deposits the streams gathered and subsequently redeposited in fluvial or lacustrine form a subordinate portion, thus giving origin to a secondary loess formation. Going beyond that field he and his supporters have apparently tried to apply this secondary factor to the explanation of difficulties in the European and American loess, to which its application is more than doubtful. It is interesting, however, to note that the loess puzzle of China, even in the mind of its chief exponent, finds a full solution only in a combination of eolian and aqueous hypotheses. The present writer herein urges the trial of a similar combination of hypotheses, but reverses the order of the terms in their Mississippian application. The aqueous loess is made primitive and the eolian loess secondary. The Richtofen loess may be said to be first eolian and secondarily aqueous; the Mississippian loess, first aqueous, and secondarily eolian. The Richtofen loess in its ultimate origin is residuary. The Mississippian loess, in its ultimate origin, is glacial. The Richtofen mode of origin may be said to be eolio-fluvial, the mode herein advocated, fluvio-eolian, in which terms the order of the words indicates the order of derivation and each word signifies a variety of loess.

T. C. CHAMBERLIN.

CRYPTODISCUS, HALL.

In a recent paper in this JOURNAL,[1] I figured and described some peculiar disk-like fossils from the Niagara limestone at Joliet, Ill., identifying them with Hall's genus *Cryptodiscus*, and interpreting them as the possible casts of the gastric cavities of Medusæ. At the time these descriptions were written a part of the material had been in my hands for two years or more. As the paper was going to press, too late for revision, additional material which suggested an entirely different interpretation, came into my hands from the collection of Mr. E. E. Teller, of Milwaukee, Wis. These new specimens are from the dolomitic Niagara limestone of Racine, Wis., and like the others are casts, the actual substance of the fossil being dissolved out. This new material shows that the disk-like bodies are not the complete fossils, but that they are attached to the summit of a tube composed of regularly arranged plates.

The disk portion of the fossil, to which Hall gave the name *Cryptodiscus*, was fully described in my former paper. It consists of an expanded disk with a variously lobed periphery, composed of four equal plates which occupy the position of the four quadrants of the disk. Figure 1, Plate A, and Fig. 6, Plate B represent the impressions of the lower and upper sides of a very complete specimen from Racine. It is similar to the specimen to which the name *Cryptodiscus digitatus* was given in my former paper, but differs from that species in the lobing of the periphery. If broken off at the bottoms of the lobes it would have the contour of *C. hydei*. The lower side of the disk with its central funnel-shaped depression with the central elevation is not different from those formerly described, but the upper side of the specimen is more nearly perfect than any of those. It is

[1] "On the Presence of Problematic Fossil Medusæ in the Niagara Limestone of Northern Illinois."—JOUR. GEOL., Vol. V, p. 744.

flat across the central portion with the exception of a small square fractured area in the exact center. This fractured portion corresponds to a similar fractured area at the summit of the central prominence of the lower side, and really represents a perforation through the disk in its perfect condition.

The impression of the upper side of the disk of another species is seen in Fig. 4, Plate A. The lobing of the periphery is different in this species, but its greatest peculiarity is in the presence of the impressions of four rather slender diverging spines, one on each quadrant, surrounding the fracture representing the central perforation of the disk.

In the limestone at Racine, associated with *Cryptodiscus*, the internal casts of some peculiar tubelike bodies have been found by Mr. Teller. Two views of the most perfect of these specimens are shown on Plate A, Fig. 3, and Plate B, Fig. 7. The tubes are composed of plates arranged in ranges of four each, and in the specimen illustrated the impressions of three such ranges are preserved. The top range consists of two longer plates and two shorter ones; the middle range consists of two plates below the shorter plates of the top range, which are placed higher than the two plates below the longer plates of the top. The lower ends of the basal range of plates are not preserved, but the summits are alternately higher and lower, to correspond with the plates of the middle range.

The specimen which forms the connecting link between the disk and the tube is illustrated on Plate A, Fig. 2. In this specimen the disk and the tube are both incomplete, but the relative position of the two is perfectly shown. The four quadrants of the disk are shown to be but the greatly expanded margins of the four plates in the top range of the tube, and the central elevation seen in the impressions of the lower side of the disk, is the summit of the internal cast of the tube.

When the relationship of the disk to the tube was recognized, the crinoidal character of *Cryptodiscus* could not be questioned; and a comparison of the arrangement of the plates in the tube with the arrangement of the plates in the dome of *Calli crinus*,

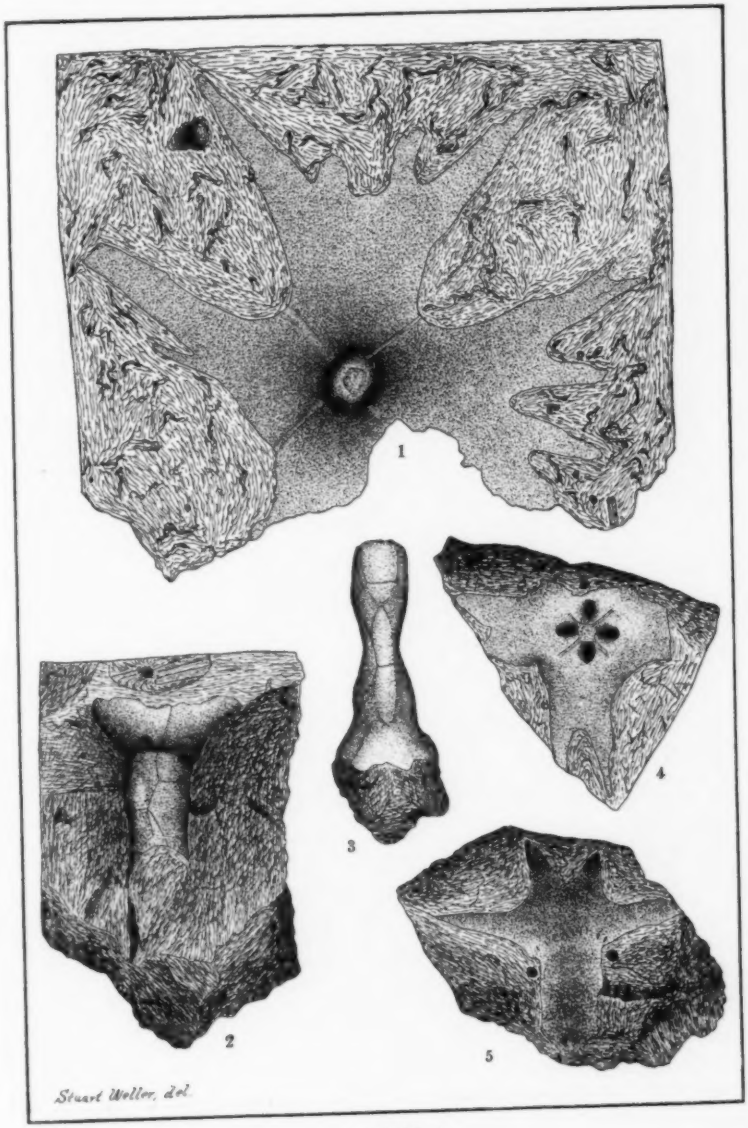

PLATE A

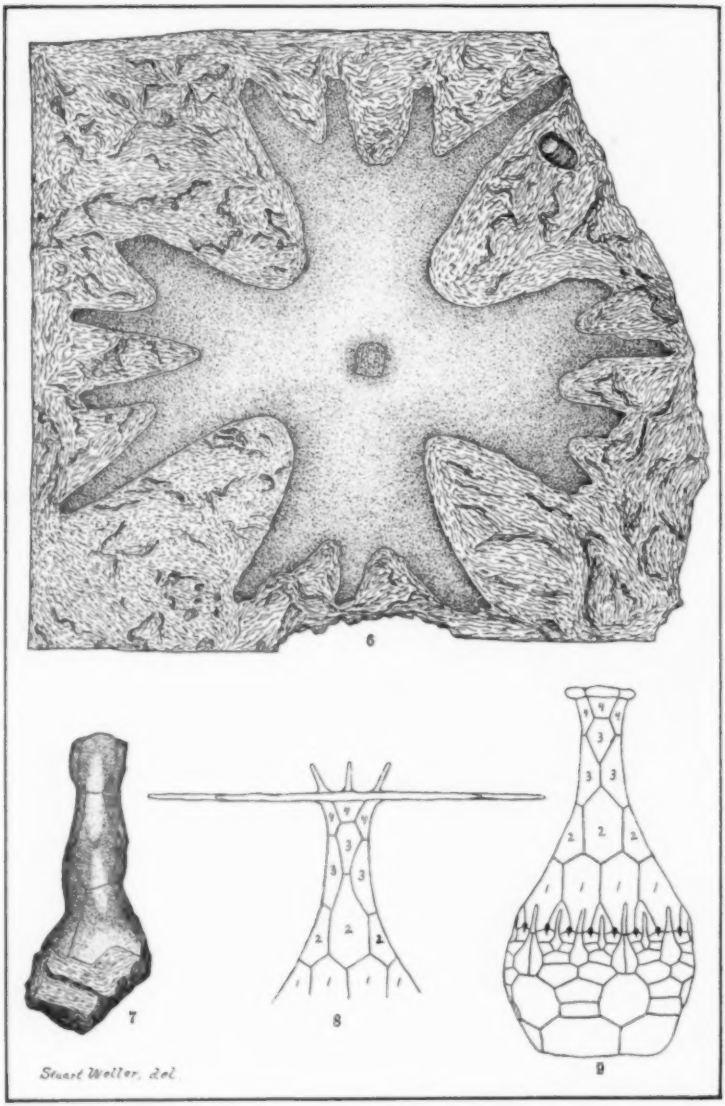

PLATE B

showed *Cryptodiscus* to be but a portion of the dome of members of that genus.

Figure 9, Plate B, is a diagram adapted from Wachsmuth and Springer, to show the arrangement of the plates in the calyx of *Callicrinus costatus* His., the type of the genus. The dome is composed of four ranges of plates, of which the first contains ten, and the second, third, and fourth ranges, four plates each.

Figure 8, Plate B, shows diagramatically the arrangement of the plates in the Racine specimen. The three ranges of plates present in these specimens correspond to the second, third, and fourth ranges in the dome of *C. costatus*. The plates in the Racine specimens differ from those of *C. costatus* in the third range; the two lower plates of this range are not in contact laterally, as in that species, but are separated by the downward extension of the two upper plates, which meet the truncated upper ends of the two corresponding plates of the second range. The most conspicuous difference between the Racine specimens and *C. costatus*, is in the greatly expanded margins of the plates of the fourth range, forming the disk to which the name *Cryptodiscus* has been applied.

Figure 5, Plate A, which shows the external impression of a portion of a disk attached to the tube, is introduced to show a peculiar ring-like canal which surrounds the tube just below its junction with the disk. This canal is open entirely around the tube so far as it is preserved, and a pliable wire inserted at one side passes around and out on the opposite side. On the impression itself, just above the angle between the disk and the tube, is a series of small slit-like openings which apparently connect with the ring canal. In the actual specimens, of course, these openings were represented by a solid ring around the tube, which was supported by a series of small bars connected with the basal portion of the under side of the disk. No explanation of these characters can be offered.

In their monograph, "The North American Crinoidea Camerata," Wachsmuth and Springer recognize from the dorsal cups alone, four species of *Callicrinus*—*C. beachleri* from St. Paul,

Ind., *C. acanthus* from Lockport, N. Y., *C. cornutus* from Racine, Wis., and Chicago, Ill., and *C. ramifer* from Tennessee. From the St. Paul beds in which *C. beachleri* occurs, Miller[1] has figured a specimen of *Cryptodiscus*. From the Racine beds, associated with *C. cornutus* the specimens illustrated in this paper were obtained. From Lockport, N. Y., and from Tennessee there is as yet no record of *Cryptodiscus*, but specimens may yet be found in these localities. The known localities for *Cryptodiscus* are Racine, Wis., Joliet, Ill., St. Paul, Ind., and Jones county, Ia., and in all these, with the exception of the last, the dorsal cups of *Callicrinus* are found associated with it.

The correlation of *Cryptodiscus* as a genus with *Callicrinus* seems complete, but material has not yet been found by means of which the species of *Cryptodiscus* may be correlated with the species of *Callicrinus* described from the dorsal cup.

The genus *Cryptodiscus*, founded by Hall, was never properly described, nor were the relationships of the fossils to which the name was applied, properly understood. D'Orbigny's name, *Callicrinus*, also has priority over Hall's, so it becomes necessary to drop *Cryptodiscus* entirely, and to refer all the specimens to *Callicrinus*. The different forms of disks doubtless represent distinct species of the genus, but there may be a difference of opinion as to whether species should be established upon the disk alone without a knowledge of the dorsal cup, and no names will be given to the Racine specimens for the present.

STUART WELLER.

THE UNIVERSITY OF CHICAGO.

[1] Eighteenth Rep. Dep. Geol. and Nat. Rec., Indiana, p. 260, Pl. I, Fig. 7.

A NOTE ON THE MIGRATION OF DIVIDES.[1]

SAN CLEMENTE ISLAND, one of a group lying off the southern coast of California, is a typical orogenic block,[2] formed by faulting in geologically recent times. Its drainage is still in its infancy, and is therefore very simple. A study of the topographical features of this isolated mass has led the writer to consider the effect on a previously established drainage system, of faulting with consequent migration of divides.

In the case of San Clemente, as the slope toward the line of faulting is by far the steeper, erosion on that side is much more rapid, and consequently the main watershed of the unmodified crust-block migrates away from that side toward the other. In this case then, the movement of the divide is from the line along which the elevation takes place—that is, from the line of faulting. This differs from an uplift along an axis, without faulting, in a topographically simple region of homogeneous rocks, as in the latter case the axis of uplift itself forms the ultimate divide, while in the former case the resulting divide is situated at some distance to one side of the line of faulting. Thus the effect on a simple drainage system already established will be different for the two kinds of crustal movements, and the law for the migration of divides as given by Campbell[3] must be modified in order to make it applicable to an uplift accompanied by pronounced faulting.

This may be illustrated as follows, assuming, as Campbell has done, the simplest possible conditions, in order to eliminate disturbing elements from the problem: In Figs. 1, 2 and 3, C represents the divide between the symmetrical drainage slopes

[1] Published by permission of the Director of the United States Geological Survey.

[2] Bull. Dept. Geol. Univ. Cal., Vol. I, No. 4, p. 129.

[3] Jour. Geol. Vol. IV, No. 5, July-August 1896, p. 580.

of the two stream profiles, C B A and C D E. If faulting occurs parallel to this divide, with a downthrow toward the left, it may occur on either side of C (leaving out of the question the possible occurrence of a fault at C itself). Suppose, first, that the fault is to the left of C, at B (Fig. 1), and that the

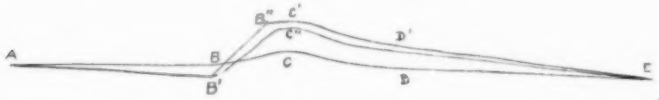

FIG. 1.

faulted portions have assumed the positions indicated by B'' C' D' E and A B', A and E representing the limits of movement in either direction.[1] The part B C will have had its angle of slope decreased by elevation, and therefore the rate of erosion on this slope will be diminished. The angle of the slope C D E, however, will have been increased, and its rate of erosion will be correspondingly greater. The slope C' D' E, then, will be cut away more rapidly than the opposite slope, C' B'', and the divide, C', will migrate toward B'', in accordance with the normal operation of the law. This condition, however, will last only a comparatively short time, for on account of the high angle of B B'' erosion on this slope will be very vigorous, and the point B'' will be rapidly carried back toward C', till the two meet. When this stage is reached the edge of the faulted block will be represented by C'', and the profile, approximately, by B' C'' E. Further erosion will tend to carry the crest C'' toward E, owing to the more rapid cutting on the steeper slope, B' C''. The final result will be that the point C'' is carried to some point such as D', the exact position of which depends on the relative attitude of the points which correspond to B' and E, when erosion has reached this stage.

The second case (Fig. 2), when the faulting is between the

[1] These sections are diagrammatic, and do not attempt to give the exact relative positions of the two parts, as these positions depend on the circumstances obtaining at the time of faulting.

divide, C, and the point E, is similar to the last in the movement of the crest of the faulted block toward D, or away from the line of faulting. In the former case, however, the initial movement (for the fault-block) was toward the fault-line, while in this case that feature is eliminated, as the faulted portion D″ E excludes

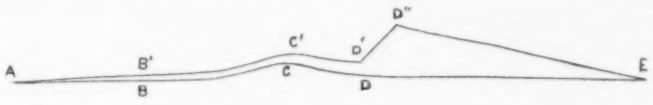

FIG. 2.

the original divide C. In this second case, this movement of the crest of the block D′ D″ E is thus away from the divide, C, also, and the final result of the uplift is the establishment of a divide for the crust-block, at some point betwen D′ and E, depending on the relative attitude of these two points.

If the faulting has been sufficient this resultant divide will form the main watershed for the region, the original divide, C being now of insignificant proportions. The faulting may, however, be such that the portion A B C D cannot be left out of account. If, as shown in Fig. 2, the final position of A B C D is more elevated than its original position, the slope C D will have been decreased, while A B C will have been slightly increased. As a consequence there will be a migration of C′ toward D′. If the faulting is sufficient in amount, the migrating crest will finally reach D′, and there will be no divide other than that of the faulted block, D′ D″ E. As the movement of the crest-line in this case is toward E for the parts on both sides of the fault-line, the resultant crest must be at some point between C′ and E, whether the amount of faulting be great or small.

If, on the other hand, the movement of A B C D is one of depression (Fig. 3), the result is more complicated, and the final position of the crest C′ will depend on the relative attitudes of the faulted portions A B′ C′ D′ and D′ D″ E. In other words, if the sum total of movement in the two parts produces elevation, the migration of the divide will be in the direction of E,

while if the resultant of the movement is a depression the divide will migrate toward A.

If the faulted block D′ D″ E were elevated from submarine depths to a position similar to that of San Clemente, the final

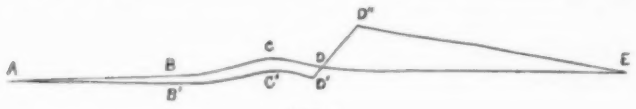

FIG. 3.

result of erosion would be a divide midway between the limiting waters on the two sides.

The results here arrived at must be true in all cases, whether the movements causing faulting are slow or rapid, continuous or intermittent in their action, and small or great in amount. Variation in these factors, however, will cause a variation in the rate of the migration, or in its extent. Other modifying factors are the relative positions of the divide and the line of faulting, and the dip of the fault-plane.

To sum up: Where simple crustal movements occur, causing faulting with resultant elevation, a migration of the stream divide will follow, in the direction of the line of faulting when the fault-scarp faces the divide, away from the line of faulting when it does not. Or, in other words, the migration is from the axis of faulting when the faulted block includes the divide, and toward the axis of faulting when it does not.

WM. SIDNEY TANGIER SMITH.

DISCOVERY OF MARINE JURASSIC ROCKS IN SOUTHWESTERN TEXAS.

SEVERAL announcements of marine Jurassic rocks in New Mexico and Texas have been made by authors, the earliest as also the latest by Mr. Jules Marcou; but the marine sediments hitherto called Jurassic in these states belong to the Comanche series. *Modiola jurafacies*, *Homomya jurafacies*, *Exogyra hilli*, and possibly one or two other members of the fauna of the latter series, which are more or less clearly analogous with fossils of the European Jurassic, should doubtless be regarded as survivals from a preceding age. Such survivals are only to be expected, and these therefore do not contradict the results arrived at by Professor R. T. Hill and Mr. F. H. Knowlton, who have shown that the lowest formation of the Comanche series presents a Wealden fauna and flora. The data of old-world stratigraphy seem to show that the Wealden formation is part of the Cretaceous system, or, more definitely, is the estuarine and arenaceous extension of lower Neocomian sediments that are elsewhere of purely marine origin and largely calcareous.

It is a principle recognized by many geologists that where the conditions afford only palæontological data for correlation and these data show a commingling of fossils of two successive systems, we should not suppose that the latest occurrence of fossils of the earlier system characterizes the highest rocks of that system, but should assume that *the first appearance of a fauna essentially characteristic of a later system, whether it be accompanied by survivals from an older fauna or not, marks the beginning of a new rock-system and age*. By this criterion Professor C. S. Prosser of the United States Geological Survey has recently drawn the line separating the Permian system from the Carboniferous in the Plains region; and in accordance with the same principle, if the prevalent European acceptation of the Cretaceous system

be adopted for America, the entire Comanche series belongs to the Cretaceous.

No true Jurassic of marine origin, therefore, has hitherto been recognized in the southern part of the United States.[1]

In 1893, when studying the Cretaceous fauna of Texas, as represented in the museum of the Geological Survey of that state, I was led to suspect the occurrence of Jurassic rocks in the vicinity of Malone, a flag-station of the Southern Pacific railway between El Paso and Sierra Blanca Junction. The evidence of such possible Jurassic formation was derived from the study of a small collection of Mesozoic fossils that had been obtained by Messrs. W. H. von Streeruwitz and Ralph Wyschetzki, according to the field-labels, "in hills about a mile northeast of Malone." The collection, though small, revealed a fauna quite different from any known in the North American Cretaceous, and one which, it was therefore surmised, might be pre-Comanche. All of the material that was deemed sufficient for study was treated of in the writer's "Contribution to the Invertebrate Palæontology of the Texas Cretaceous," in the Fourth Annual Report of the Texas State Geological Survey. It included six species, all apparently new to science, which were described under the following names: *Anatina tosta*, *Cucullæa transpecosensis*, *Cyprina* (*? Roudairia*) *streeruwitzii*, *Trigonia vyschetzkii*, *T. taffi*, and *Venus malonensis*. These fossils threw little light on the question of Jurassic or Cretaceous age of the rocks in which they occurred, as all of the genera were known to be common to both of these geological systems, and the two species of Trigonia were regarded as presenting features that allied them to both certain Jurassic and certain Cretaceous trigonias. The problem was therefore left unsolved.

Besides the Malone hills, the only locality where any fossil

[1] The Morrison Formation (Cross) of Colorado and Wyoming was traced along the front of the Rockies many years ago by Dr. F. V. Hayden at least as far south as Las Vegas, and its occurrence at the latter point has been recently confirmed by Professor Alpheus Hyatt. But this, though it has usually been called Jurassic, is now beginning to be regarded by some as probably lower Cretaceous (Wealden), and, whatever its age, is a fresh-water formation.

purporting to belong to the same fauna had been collected was Bluff mesa, upon which Mr. J. A. Taff of the Texas Survey had obtained part of the type-material of *Trigonia taffi*, the remainder being labeled as from the Malone locality. The rocks of Bluff mesa having been referred by Mr. Taff to the "Washita division"[1] (though the fossils he named from them were Glen Rose species) there was literary evidence that seemed to connect the Malone fossils with the Comanche series. Awaiting further light, they were therefore left among the fossils of that series. The "Washita" intended by Mr. Taff included both the true Washita, as originally established by Dr. B. F. Shumard under the name, Washita limestone, and the Denison formation of Professor Hill.

I did not, however, feel satisfied with this disposal of them, and I determined to reëxamine the matter at the earliest opportunity. This came in a journey made to Guaymas, Mexico, in the spring of 1895, by my friend, Mr. Robert W. Goodell, who, at my request, and assisted by his father, Mr. R. R. Goodell, very kindly made a side trip to the Sierra Blanca Mountains and the Malone hills to obtain further collections and data from those localities. From the Sierra Blanca Mountains, one of the localities of Comanche rocks nearest to the Malone hills, the Messrs. Goodell brought back many species of Mesozoic fossils, all of them apparently from Comanche rocks, most of them Washita forms, and many of them profusely abundant, but not one of them identical with fossils of the Malone hills. The Goodell collections from the Sierra Blanca Mountains and the Malone hills not only emphasized the distinctness of the fauna of the latter locality from that of the Comanche series, but they also settled the age of the Malone fauna. For, from the Malone hills they included, besides three of the species collected there by earlier explorers, several other forms, all of which seemed to be new to science,[2] and one of which was a

[1] Second Annual Report of the Geological Survey of Texas, pp. 719, et seq., and Plate XXVII.

[2] Since this was written, two of these forms have been found to be probably identical with two fossils that have been described from the Jurassic of Mexico. See footnote relating to *Pleuromya* and *Lucina*.

Trigonia of the section, *Undulatæ*, a type exclusively characteristic of Jurassic rocks. This beautifully ornamented shell is of medium or smaller than medium size in the genus, ovate, strongly inflated, and has the partly continuous and partly tuberculated ribs abruptly angulated. I have named it, after Mr. Robert W. Goodell, *Trigonia goodellii*. Moreover, a careful reëxamination of *Trigonia vyschetzkii*, made possible by the new material in the Goodell collection, indicated that it belonged to the *Clavellatæ* section of its genus, a section chiefly of Jurassic occurrence. As Trigonia is, among lamellibranchs, relatively important as a means of stratigraphic diagnosis, and as none of the Malone fossils agreed with species known in the lower Comanche, the evidence from the Goodell collection has led me to refer the Malone fauna and formation to the Jurassic system.

The vicinity of Malone was visited but once by the Messrs. Goodell (March 30, 1895), and then for only part of a day, their journey thither having been made from Sierra Blanca by wagon.

I am indebted to the kindness of Mr. Robert W. Goodell for the use of his field notes on the Sierra Blanca region, and particularly for those on the Malone hills, which include a section across the latter at a point considerably west of that at which Mr. R. R. Goodell collected the fossils and presenting different but apparently related conditions. His Malone hills notes are as follows:

A careful search of the western end of the line of hills one mile N. E. of Malone failed to reveal any fossils. The following is a section across the western end of this line of hills.

Bearing [magnetic] of line from station to beginning of section-line, N. 70° E.

Bearing [magnetic] of section-line, N. 20° E.; one-half mile from station. [Malone station.]

1) 340 feet heavily bedded limestone; no fossils; seams of calcite abundant; dip———; labeled M.

2) 30 feet coarse gypsum; dip 75° S. 40° W.; labeled N.

3) 10 feet laminated gypsum; dip 75° S. 40° to 50° W.; labeled O.

4) 50 feet red grits interspersed with seams of gypsum of various widths; dip 75° S. 40° to 50° W.; labeled P.

5) 110 feet coarse gypsum, same as N.

6) 450 feet heavily bedded limestone, with many seams of calcite which in places are several feet wide. That is, there are places several feet wide where there is more calcite than limestone. Dip hard to get, but at one place halfway across the bed it was 75° N. 40° E.; labeled Q.

General direction of hills nearly E. and W. The water has worn out a little draw in the gypsum beds between the limestone.

Several hundred yards west of where this section was made, at the extreme N. W. end of these hills, near the R. R., is an outcrop of soft sandstone. Parties have opened this up in one or two places, in search of fossils perhaps, but I could find no trace of any.

About a mile east of where I made this section, between the last two hills of this series, R. R. Goodell found an outcrop carrying fossils; a large clam, a Trigonia with rough nodular ridges, and two other bivalves. Outcrop 500 feet long, 150 feet wide; strike N. and S.; dip about 20°E.

Instead of four species of bivalves, however, the collection which the Messrs. Goodell brought back from this locality included seven, besides a fragment of an eighth and one of an ammonite. The bivalves included *Pholadomya tosta* (which the Goodell collection showed had been erroneously referred to the genus, *Anatina*); *Trigonia vyschetzkii;* the new Trigonia of the Jurassic section *Undulatæ*, *T. goodellii;* a subcircular, strongly compressed shell which is either a *Cyprimeria* or a *Lucina*, and to which I have given the MS. specific name *metrica*, from its being ornamented with concentric, sharply raised lines disposed at ample and remarkably regular intervals; a plain or gently and irregularly concentric-undulate, elongate *Pleuromya—P. malonensis* of my MS.,[1] showing in several examples the overlapping of the left hinge-margin by the right, characteristic of this genus; the *Venus malonensis*; an indeterminate ostreid (shown only in section, imbedded); and a fragment of another shell, possibly a *Trigonia* of the section, *Costatæ*. The *Pleuromya* bears more or less resemblance to *P. henseli* Hill, a Glen Rose species which the writer has collected at a number of localities

[1] Since this and the preceding species were studied, drawn, and named, I have recovered a mislaid copy of Castillo and Aguilera's "Fuana Fosil de la Sierra de Catorce" (Boletin de la Comision Geologica de Mexico, Num. 1), and it seems to me that there can be little doubt of their belonging respectively to the *Pleuromya inconstans* and *Lucina potosina* of those authors.

in north-central Texas and which is especially abundant in Hamilton county of that state. Specimens of both species, as usually preserved, vary somewhat in shape owing to mechanical distortion, and it is difficult to determine their precise natural form. Apparently, however, the Malone species differs from the *P. henseli* in having its posterior portion less tapering and a little recurved. The ammonite fragment did not show the suture; but the form and ribbing indicate a type common in the upper Jurassic.

As shown by the the rock adhering to fossils in the Goodell collection, the fossiliferous strata of the Malone hills consist in part of hard yellowish to brownish gray calcareous sandstone or arenaceous limestone. The sandy component is largely the débris of acidic eruptive rocks of undetermined varieties. But it seems probable that the massive, calcite-seamed limestone and the gypsum occurring in the more westerly part of the same hills and across which Mr. Robert W. Goodell's section was taken, are closely associated and should be referred to the same formation with them; and if so the similar gypsums and massive limestones of Malone Mountain, described by Mr. Taff as the *Malone formation* (which in several respects the Goodell section duplicates), is a prominent part of that formation. For the formation, therefore, provisionally regarded as embracing the fossiliferous sandstones and limestones, the gypsums, the massive calcite-seamed limestones, and any other rocks included among these, of the Malone Mountain and the hills north and east of Malone Station, Mr. Taff's name *Malone beds*, or Malone formation is appropriately retained. The Malone formation thus assumes wider limits, a different age-significance, and far greater importance than were assigned to it by Mr. Taff. Yet to him belongs the credit of having published the first section from it, and of having called attention to the fact that the Malone uplift is older than other orographic features of the Sierra Blanca district.

The Geological Map of Mexico, published by the late Director of the Geological Survey of Mexico, Señor Castillo, shows a

limited area of Jurassic rocks in northern Mexico, not far southwest of Saltillo. This is apparently the nearest known occurrence of marine Jurassic rocks to that here announced, being distant from Malone some 500 miles in a southeasterly direction. The discovery of Jurassic rocks in El Paso county, Texas, therefore, raises the interesting question whether other limited areas of Jurassic may not yet be discovered in intermediate territory.

This article in major part, including definite reference of the fossiliferous beds of the Malone hills to the Jurassic upon evidence derived from the Trigonias of the Goodell collection, was first written in the latter part of 1896. Its publication was postponed, — with some revision of the manuscript in the meantime, — in the hope that I might soon visit the formation in person and secure more abundant data. This I was unable to do till August last. Reaching the vicinity on the nineteenth of the month, I spent about three weeks exploring some of the localities accessible from Sierra Blanca station, devoting principal attention to the Malone fauna and formation. The large collection of fossils made from the latter, so far as yet studied, confirms the reference to the Jurassic. I at first intended to incorporate the results of this trip with those derived from the Texas Survey and Goodell collections and data ; but it has seemed best to publish deductions from the earlier data without the further delay involved in the study of this season's material, and to present the results of the latter study, when completed, in separate articles.

When this article was first written, I did not have access to the first number of the Boletin de la Comision Geologica de Mexico, containing Castillo and Aguilera's "Fauna Fosil de la Sierra de Catorce," my copy of it having been temporarily lost in the exigencies of a change of residence. The missing document has since come to light, and the independent reference which I have made of the Malone fauna to the Jurassic, is confirmed by it, *Pleuromya inconstans* and *Lucina potosina* being apparently common to the Malone and the Alamitos ("upper Jurassic") formations (as elsewhere indicated in footnotes), and

the ornamentation of the Malone ammonite fragment apparently agreeing with that of the Alamitos form, *Hoplites bifurcatus*.

In conclusion, I regret to have to record the recent decease of Mr. Robert W. Goodell, which occurred at his home in Houghton, Michigan, on the 23d of September last, and in his 28th year. I regard his early calling away, not only as a personal bereavement, but as a distinct loss to science as well; for, though an invalid, and unable to bear the confinement involved in the elaboration of his out of door observations, he was a young man of unusual intellectual ability and promise and an enthusiastic and careful observer. He had done considerable field work on the Laramie, Denver, and Fort Union formations in the area between Denver and Colorado Springs, and on several other matters of Colorado, Texas and Michigan geology; and, as appears in the present article, it is to his zeal as a scientific explorer that we owe the trip to Malone which, aided by his father's more robust physical strength, resulted in the means for the first satisfactory diagnosis of the age of the Malone hills fauna; and in an important advance in our knowledge of the distribution of North American Jurassic rocks.

F. W. CRAGIN.

COLORADO SPRINGS, COL.

ANDENDIORITE IN JAPAN.

In the northern fringe of the Kwanto plain, the environs of Tokyo, there is a series of volcanoes, including Asama, Haruna, Akaki, Niko, and Nasu, some of which are active, while the others are totally extinct. One of the oldest rocks erupted from these volcanoes is exposed at Usui Pass, in the form of propylite. The pass makes several trends along the steep, rocky slope of propylite mountains, and the railway of the Abt system passes through the rock by means of twenty-six tunnels. The propylite directly overlies the Miocene beds.

The propylite seems to have been derived from augite-andesite; the normal variety has a homogeneous aspect, looking like a common andesite. The usual forms are altered. They are white or pale greenish, with scattered granular or sometimes cubical crystals of pyrite. Yellowish epidote grains and calcite crystals are also distinctly observed.

Midway between the telegraphic posts No. 367 and No. 368, on the same pass, I have seen, piercing through the above mentioned propylite, an interesting diorite dike, extending in an east and west direction. The eastern part of the dike is coarse-crystalline, while the other end is fine-granular or somewhat porphyritic.

The diorite, which is manifestly younger than the Miocene beds, is a hypidiomorphic aggregate of plagioclase and hornblende, with quartz, magnetite, iron pyrite, and remains of augite, sometimes mixed with hornblende. Epidote and chlorite, besides secondary pyrite, are also very common as secondary products. The plagioclase is distinguished with the naked eye as milky white grains, while the hornblende is greenish black, with a resinous luster on the newly cleaved surfaces. Iron pyrite and epidote grains are always found on the fresh surface of the rock, with their characteristic colors.

The plagioclase, which is the most important essential

ingredient in the rock, under the microscope is somewhat clear and fresh, exhibiting the extinction angle of labradorite. The albite type is the most common among twins, and the pericline type, also, is frequently found in the same individuals. Zonal structure, with different optical orientation, is often met with. Sometimes the core exhibits an eight-sided section, while the outline of the whole crystal is nearly rectangular. The crystal is often partly idiomorphic and partly allotriomorphic. It usually contains glass enclosures, which are seldom zonally arranged. Sometimes immovable gas bubbles are seen. The presence of liquid enclosures is very uncertain. The feldspar is generally fresh and clear. Decomposition begins at the cracks, where epidote grains are produced. In some cases they entirely replace the feldspar.

Next to the feldspar, the most abundant mineral is hornblende, either fibrous or compact, which fills up the interspaces between feldspar crystals. The characteristic cleavage along (110) is very distinct. The prevailing color is green, with the following pleochroism: **a** = greenish brown, **b** = brownish green, **c** = green. The extinction angle is about 12°, but the decomposing individuals exhibit an undulatory extinction. Many of the hornblende crystals are derived from augite. The sections of the latter are brownish in color, with a greenish tinge, compact in texture, with their characteristic cleavage and an extinction angle of about 38°. Sometimes such a compact augite is converted into one with granular texture, each of the grains retaining the optical property of augite. The granular augite is converted into fibrous hornblende. These fibers are generally united in bundles, parallel to each other. The vertical and orthoaxes of the primary augite and of the secondary hornblende are nearly always in parallel position, sometimes forming a pseudomorph of hornblende after augite, which is distinctly seen in cross section. The green fibrous hornblende is further decomposed into epidote grains or chlorite. Occasionally all these stages of alteration may be seen in one section, surrounding each other in regular order.

Quartz which is surely primary is totally allotriomorphic, and fills up the interspaces between feldspar crystals. It is always fresh, contains glass enclosures, and sometimes well-shaped crystals of pyrite.

Magnetite is very common. An opaque ore, perhaps ilmenite, undergoes decomposition in such a manner as to leave more resisting lamellæ cutting each other at 60°. The pyrite contained in quartz is certainly of primary orgin.

Notwithstanding the holocrystalline structure of the rock, there are, occasionally, remnants of groundmass, which consist of microscopical grains of plagioclase, hornblende and iron ores. In a fine granular, porphyritic variety of the diorite, phenocrysts of feldspar are scattered in the aggregate of smaller lath-shaped feldspar individuals, which corresponds to the groundmass of the neovolcanic rocks. The above mentioned facts seem to show that the diorite is not a normal plutonic rock, but most probably a sheet or dike, which has solidified in the region of slight pressure.

Contact metamorphism.— In the neighborhood of the diorite, the propylite is so highly decomposed that traces of the contact metamorphism cannot be recognized. Although the Tertiary beds are never found in contact with the diorite dike, a Tertiary shale found about 330 feet to the north of the diorite is hardened like a hornstone and contains iron pyrite, which is not usual with the unaltered shale of the region. This change of shale seems to be due not to the action of the propylite lying between the diorite dike and the shale but to the diorite itself, which, in fact, has been taken out from a railway tunnel excavated close to the exposure of the shale. It seems probable that similar diorite dikes run through the Tertiary beds everywhere beneath the surface, because we frequently find hardened shale with a contact mineral, whose exact nature has not yet been ascertained.

Stelzner [1] describes a quartz-bearing mica-diorite of Argentine under the name of "Andendiorit" as a neovolcanic dike

[1] STELZNER, Geologie u. Palæontologie von Argentina, p. 213.

rock in the following words: "U. d. M. beobachtete man sehr deutlich Plagioklas, Quarz und braunen Glimmer; daneben scheinen auch noch kleinen Menze von Orthoklas und Hornblende vorhanden zu sein. Der Plagioklas ist sehr frisch, wasserhell, hier und da etwas rissig; er hat oft zonalen Bau beherbergt, wieder die oben bereits mehrfach beschriebenen Glasseinschlüsse von der Form negativer Krystälchen mit anhaftenden opaken Körnchen, ferner einzelne Flüssigkeitseinschlüsse, Dampfporen und farblose, sowie blassgrüne Mikrolithen. . . . . Die Hornblende tritt uns vereinzelt auf, und ist bereits durchgängig stark zersetzt und zerfasert."

The diorite at Usui Pass is also a Tertiary eruptive, and closely resembles Stelzner's andendiorite in the microscopical properties of the plagioclase, especially in the zonal structure and the glass enclosures with attached opaque granules, which are nearly always absent from the true plutonic diorite.

C. IWASAKI.

KYOTO, JAPAN.

STUDIES IN THE DRIFTLESS REGION OF WISCONSIN.[1]

THE superficial deposits of this region, aside from the interest which would naturally attach to any such deposit, possess a certain special interest due to the relation the region holds to the adjoining glaciated territory, and the presumption that they might furnish a record of certain subsidiary facts which from the nature of the case the glaciated region itself could not furnish.

The field as a whole is a most inviting one for study, presenting as it does considerable variety. But the purpose of this article is more especially to describe a particular deposit as seen in the vicinity of Trempealeau on the Mississippi River. As some knowledge of associated beds is necessary to a full understanding, I will briefly describe them in order beginning with:

The loess.— From the upper limits reached by the Champlain floods, all the smaller valleys, the lower hills, and, in a less degree, the higher hills are covered by a bed of clay, the average thickness of which may be between twenty and thirty feet, but it

[1] Early in 1894 Mr. G. H. Squier brought to the attention of the senior editor of this JOURNAL some observations which he had made on ridges of coarse gravel and bowlders in the vicinity of Tomah, Wis., which lies in the heart of the driftless area. It was his opinion that the formations constituted evidence of local glaciation. The débris was described as made up of chert and sandstone too coarse to be easily accounted for, in his opinion, by floods. It formed ridges on the slopes or side-plains of the valley and neither had the form of definite terraces nor of axial valley drift. No glacial striation either of the transported rock or of the rock *in situ* were observed, nor were glacial contours recognized in the configuration of the valley, nor distinctively in the ridges of débris. These deficiencies of evidence seemed less important however than the apparent absence of limestone débris. The deposit in question seemed to be made up wholly of sandstone, chert, and other residuary material. As limestone lay on the summit and formed the protecting crown of the highlands in which the valleys head, and as its habit of outcrop is such that it could readily yield massive blocks to glaciers occupying the heads of these valleys, and further, as limestone is habitually present in morainic débris formed in such situations.

varies greatly. Two measurements obtained not over ten rods apart, one on the crest of a hill, the other on its west slope, gave seventeen and thirty-two feet, respectively, with indications that at some intermediate point it may reach fifty feet. It is almost wholly free from stones and very homogeneous in texture, though the deeper parts are somewhat lighter in color and more friable, the result apparently of a large admixture of sand. Save in the valleys, it usually overlies the residual material derived from the disintegration of the underlying rocks, or near the foot of the hills, the talus, which being often nearly pure sand well shows the abruptness of the transition. In rare cases it rests directly on the rock.

while it is habitually absent from accumulations formed by weathering and by processes sequent upon weathering, the balance of evidence seemed to me adverse to the glacial hypothesis. At any rate, it seemed best to urge more prolonged and critical study before publication.

In February 1895 Mr. Squier presented similar data more fully worked out with reference to ridges of bowldery material accumulated about Trempealeau bluff on the Mississippi, in the northern part of the driftless area. The absence of limestone cannot be urged here with the same force as at Tomah, since it occurs in at least one locality. The absence of glacial scratches on the transported rocks as well as the valley sides, and the lack of specific morainic contours leave much to be desired here as at Tomah, but these deficiencies are not necessarily fatal to the glacial hypothesis. The conception of Mr. Squier, that the glaciers were formed by snowdrifts lodged in the valleys, and not by summit accumulations, is doubtless the true one if the glacial interpretation be true at all. Examples of such snowdrift valley glaciers occur in the extra-glacial belt in Greenland, and might reasonably enough be supposed to have occurred in the driftless area. But if these deposits are really due to local wind-drift glaciers decisive evidence of the fact should be forthcoming on a sufficiently prolonged and critical search. A coarse massive mixture of residuary material, however difficult of satisfactory explanation by other agencies, cannot safely be taken as in itself proof of glacial origin. It must be remembered that as a result of the excessive superficial thawing and freezing incident to glacier-border conditions, the facilities for landslides, bodily creeps, and similar modes of movement reached an extraordinary degree of development. I have seen in Montana a modern landslide that imitated a glacier almost perfectly in the deployment of its material. In Yellowstone Park, Mr. Hague showed me several years ago an almost perfect imitation of glacial deployment assumed by a talus mass of angular blocks of igneous rock. When such formations consist of mixtures of earthy and rocky material, their positive differentiation from glacial deposits may not be always successfully attained. So long as the constituent material is essentially residuary in origin, and there is an absence of any notable quantity of unweathered rock

Stratified beds.—In the valleys up to about one hundred feet above the river, the loess usually overlies stratified beds. The upper surface of the main body of the beds is not as high as given, but beds of similar character, of no great thickness, persist for a short but indefinite distance up the hillside. The thickest section I have seen shows about fifteen feet without exposing the base. In composition, sand forms by far the most abundant element, especially in the thickest places. Clay is present however, in some places interstratified with sand, and stones not exceeding a few pounds weight are plentifully included, all of local origin. The transition to the overlying loess is abrupt.

Peculiar stratum.—In one valley there is exposed a bed which, though of small size (four feet thick, and but a few rods in extent), possesses considerable interest from the fact that it contains pebbles of extra-local origin (granite, etc.). It intervenes between the stratified beds and the loess and is sharply distinguished from both. It is entirely unstratified, but presents a somewhat mottled appearance due to the imperfect mingling of the component elements, sand, clay, etc. It also contains stones of local origin not exceeding a few pounds weight. Its position both stratigraphically and topographically is such that it cannot be referred

wrested from its place as glaciers are accustomed to wrest a portion of their burden the suspicion of an origin by creep or slide or wash, or at least of some origin other than glacial, is invited.

But in view of the recent article by Mr. Frederick W. Sardeson in the December number of the *American Geologist*, in which the occurrence of glaciation in the driftless area is confidently announced on the basis of much more limited studies than those of Mr. Squier, and upon formations much more open to doubt than those near Tomah and Trempealeau, since they are described as wholly composed of sandstone, chert and earthy matter all referable to the residuary class, while the crowns of the ridges which closely overlook the valley on both sides are limestone, it is obvious that it might be unjust to Mr. Squier to urge longer search for the desired critical data before publication. It is even possible that this urgency in the past and the delay in the publication of his observations may not be free from the appearance of injustice. But fortunately the good judgment of geologists does not, in the better habit of today, rest much upon technical priority, but almost wholly upon the care and the completeness of the investigation. It has seemed only fair to Mr. Squier, however, to state thus fully the extent of his studies and the occasion of the delay in their published appearance.

T. C. CHAMBERLIN.

to the time of the river gravels, but must be assigned to some earlier period.

Unstratified beds.—Overlaid by the stratified beds where they occur, otherwise by the loess, are certain deposits, which more especially form the subject of this article. They are confined to the valleys, where they have a much greater range than the stratified beds, reaching from two hundred feet or more above present river level to an unknown depth below. They consist characteristically of an aggregation of stones large and small together with the finer material forming the matrix. Although there is a considerable range of variation in the abundance and average size of the stones, in the relative abundance of the different kinds, and in the composition of the matrix, the general facies remains very constant. All the material so far as discovered is of local origin. Owing to a variety of circumstances it is difficult to give the thickness with anything like accuracy.

Details of structure will be best shown in the course of a description of the various exposures. The beds are for the most part entirely concealed from observation by the overlying deposits. It is only in the vicinity of the river where the latter have been wholly or partly removed, or where a deep ravine has penetrated to them that they can be studied.

Descriptive details.—The most extensive exposures occur about a mile and a half west of Trempealeau village. A sketch map of the locality is given in Fig. 1. At this point two old valleys converge so that they partly unite along the river front. The lower parts of these valleys (shown in outline on the map) have been filled up so that the drainage has been deflected, resulting in the formation of new gorges through the rock. Wherever these fillings are open to observation they are seen to consist of unstratified beds having the general characteristics above described. In the east valley loess occurs down to the bottom of the ravine above the filling, many feet below its crest.

The west valley offers rather the most favorable conditions for observation and section 2, Fig. 2, is taken along its axis. The filling takes the form of a well marked ridge extending across

the old valley. It is considerably broader and higher at the east end. At the west end it has been considerably encroached upon by the torrent course. At this end where it abuts against the

Figure 1.

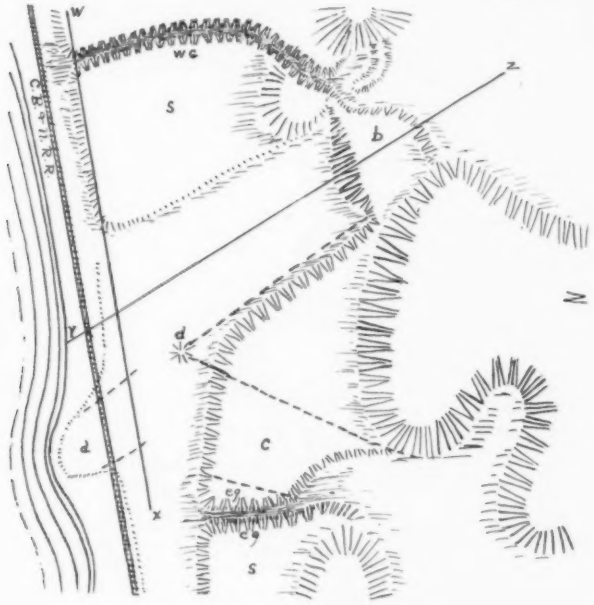

FIG. 1.—Sketch of map of vicinity of Trempealeau, Wis., described in text. Outlines of valleys in broken lines. *wg*, Rock gorge of west valley; *eg*, Rock gorge of east valley; *a*, Point composed of large rock masses; *b*, Transvesre ridge; *c*, Filling of east valley; *d*, Outlying low knob; *ss*, Sandstone plateaus; *wx*, *yz*, Lines of sections.

side of the valley, it meets a projecting spur from the hills, and through this spur the upper end of the rock gorge passes. Surface indications show that material similar to the ridge extends down the east side of the valley as far at least as the low knob *d*, Fig. 1, but its center along the line of section is occupied by nearly pure sand. On the west side gullies show that a bowlder bed

probably exists a few feet below the surface. Above the ridge loess begins and covers all the upper part of the valley. It is seen in the bottom of the ravine as it skirts the ridge, some twenty feet below its crest.

From the knob *d* a concealed ridge extends toward the river terminating in the prominent point *a*. The front of the point is lined with very large masses of rock reaching up to six or seven tons in weight. Excavations show that the entire ridge is composed of like material. The largest masses are usually sandstone. Chert is abundant and all the local rocks are represented. Sand covers the ridge to a depth of two to three feet and fills the valleys on either side to an unknown depth. The general direction of the ridge is shown by occasional protruding bowlders. As shown on the map, this ridge extends almost entirely across the course of the east valley. Yet its direction and other circumstances seem to indicate that it belongs structurally to both valleys.

About half a mile east of the two valleys just described occurs another, the largest in the Trempealeau bluffs. (It is the one in which the bed containing pebbles of extra local origin occurs.) At its mouth, on the east side, a bowlder bed is superimposed on the edge of a sandstone plateau (sec. 3, Fig. 2). In the size and character of the material, in structure, etc., it is a fairly representative example, although not as thick as most. No similar deposit is to be seen on the other side, although I should expect to find one under the sand. In the upper parts of this valley some interesting sections are furnished by washouts; owing, however, to their incompleteness they, for the most part, leave one in doubt as to the true nature of the structure displayed.

In one place the point of a hill has been washed away, showing that at that point the hill consists of a bowlder bed of characteristic type, the material being piled nearly as steeply as it will lie. The top and sides are covered with loess. The entire junction is visible, showing that the transition is as abrupt as possible (sec. 4). It cannot be seen whether it is part of a

ridge stretching across the valley or not. Less than a quarter of a mile east of this valley is another small one descending from the west side of the principal bluff. It first leaves the

Figure 2.

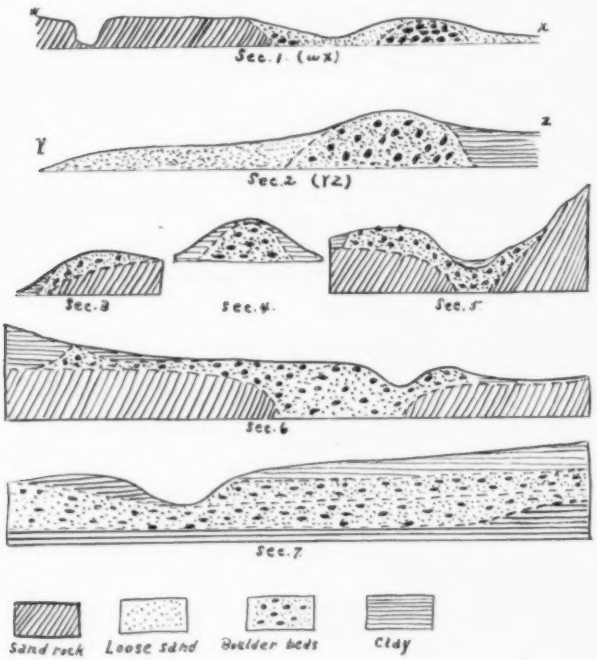

FIG. 2.—Section near Trempealeau, Wis. Scale about 240ft to an inch, except in Sec. 7, which is about 65ft to an inch. Datum, river level, except in Sec. 7.

confinement of the hills on the west side, at the same time changing from a nearly westerly to a southerly direction. Along this west side a large ridge of heavy bowlders is superimposed on a sandstone table. As the sandstone table falls away toward

the river the ridge also descends until it becomes merged with a bowlder bed which spreads out laterally to a moderate extent. Along the river front, this is cut into by the railroad excavation. The deposits are characterized throughout by the large average size of the material (equaling in this respect the ridge *a*, sec. 1) and by the abundance of limestone which forms masses at least as large as any. A smaller bowlder ridge can be seen on the east side after it leaves the hills.

Section 5 is made where the valley is still confined by the hill on the east.

Another valley, about the size and character of the last, descends from the eastern side of the same bluff and debouches into the center of Trempealeau village. In this case, also, a ridge extends across a sandstone table on one side, from the point where the valley leaves the hills. On the other side the valley skirts the foot of one of the main bluffs where the slope is gentle and the sides thickly covered with loess. A deep excavation has been made into this hillside for street construction. It shows the bowlder bed extending under the loess for a short distance, then suddenly rising into a ridge and as suddenly falling off. There appears to be a transverse ridge about where the line of section (sec. 6) runs, but it is not well defined. It is a difficult section to show.

In this valley the torrent course, after cutting through from forty to fifty feet of loess, has cut in places fifteen or twenty feet into the bowlder beds, thus giving opportunity for the study of the internal structure not elsewhere obtained. As, however, the section is not fresh it is only by much labor that it can be made available. It shows the bowlder beds alternating with beds of clay similar in appearance to the loess. Near the lower end of the ravine two bowlder beds occur above the bottom of the ravine and a hole seven feet deep in the bottom of the ravine struck the top of a third.

The thickness of a single bed ranges from about six to ten feet, varying considerably at different points. Roughly speaking the clay partings have about the same thickness as the bowl-

der beds. The general slope of the beds is only about one-third that of the ravine, so that they soon disappear from view, but further up the ravine and about thirty feet above the calculated horizon of the highest of the lower beds another one occurs about four feet thick, the parting being all clay. There appears to be another bed still further up.

In all the sections examined the extreme abruptness of the transition is noteworthy, the clay up to the very line of junction being absolutely free from stones.

Owing to the great labor of obtaining sections, and their small extent when obtained, it is impossible to answer many important questions regarding the form, extent, and relations of the beds.

Section 7 is fairly representative of the aspect of the beds in sections parallel to the valley. The relations shown at *p* were worked out carefully, and are of considerable interest. The upper bed, which terminates rather abruptly at that point, has a matrix composed mainly of sand, while in the lower bed the matrix is a compact clay. The transition from one to the other is quite abrupt.

Causes. — Although I should not like to express a final opinion as yet, I will, nevertheless, say that so far as the facts are known they seem to very strongly indicate one agent, while equally excluding others.

The agents capable of transporting material of the weight above described are few. Some of these may be dismissed with few words. Simple gravity, such as forms the talus of the hills, is excluded, since all the typical examples lie far outside its range of action. Wave action is also excluded. Neither can shore-ice offer any adequate explanation, although it can scarcely be doubted that it existed, and certain widely scattered bowlders, as well as certain sharply defined small pockets of local pebbles occasionally found embedded in the loess, may, with great probability, be assigned to this agent. Practically there are but two agents which need be considered. The one is torrential, the other, glacial action, in either case

operating during a period of subsidence, more or less interrupted by periods of partial reëlevation.

Torrential action.—Considered in the light of inherent probability, as well as in certain general aspects, this agent is doubtless the one we should select. The formations are strictly valley deposits. Torrents necessarily existed and must have produced characteristic deposits, and some of the beds at least might have been so formed. When, however, we take account of specific characteristics we find very grave difficulties, such as the transverse ridges. To account for these at all by torrential action it is necessary to regard them as ridges of erosion, the remains of a formation once occupying the entire upper part of the valley. The sequence of events which would thus be indicated is something as follows: (1) Subsidence, unstratified deposits; (2) Elevation, erosion; (3) Subsidence, stratified beds and loess, but no unstratified beds; (4) Reëlevation, erosion.

A study of local conditions furnishes several reasons why such a sequence of events must be regarded as violent and improbable. I will mention but one which alone seems to me to be fatal to it. As already stated, in the west valley above the ridge:

a. The loess covers everything high and low, even to the bottom of recent gullies, within a couple of rods of the upper end of the gorge, and a foot or two higher than its rock floor. Unless, therefore, we suppose that the gorge has received no appreciable deepening since the last elevation we must suppose that the early erosion extended deeper above the gorge than in the gorge itself. (How much deeper the loess extends, I do not know.)

b. The lateral ridges.—Not to occupy too much space I will refer to but one, the ridge marked *a* on the map. Assuming the two valleys to have been filled to the height of the ridge we should have to account for the removal of a very large amount of material, exceeding in the west valley the amount removed from its own gorge, yet its drainage area as compared with that

of the gorge is only as about 1 to 100. It would, morever, be necessary to account for the removal of material to a point considerably below present river level, which could only have been possible during a period of greater elevation, of which the gorge gives no indication.

c. There is excellent reason for believing that no torrents could have existed in these valleys capable of transporting the heavy bowlders found in the deposits. Of course I do not deny that torrents of sufficient power exist. I simply assert that in this as in all cases the question must be decided on the basis of local conditions. During the years that I have been familiar with the locality there have occurred several very heavy rains, and one of terrible severity, but never have I seen material transported reaching even the hundredth part of the weight of masses occurring in the deposits in question.

Moreover, a degree of subsidence sufficient to have allowed these deposits by such agency would have brought the valleys into the condition of broad flats with gentle slopes in which powerful torrential action would have been out of the question. We have also in the stratified beds, deposits formed under the conditions assumed, and having the characteristics we should expect.

Local glaciers.—That these, if we can suppose them to have existed, could have produced the specific effects above described, will not, I think, be questioned. I will, therefore, confine further remarks to facts having a negative bearing. Some of these have been anticipated in speaking of those favoring torrential agency. A further fact is that no undoubted case of glacial polishing or striation has yet been found, either on transported material or on the valley walls. The force of the objection is, however, practically destroyed by the fact that so far I have found only three exposures of rock so situated as to have fallen within the range of glacier action, while the transported material in sight, has been carried but a short distance and the greater share of that over beds of earlier deposit.

A more serious objection might be based on the general

insufficiency of the conditions for the production of glaciers. The present maximum height of Trempealeau bluff is but 548 feet above the river. It was, of course, less at that time in proportion to the amount of submergence.

But even were the elevation sufficient to allow of the formations of snow fields on the hilltops, and not elsewhere, still as most of the hills are little more than sharp ridges it would be quite impossible that the snow fields should have possessed volume sufficient to originate glaciers.

My own opinion is that under the influence of the wind the valleys themselves received a much larger annual accumulation of snow than would fall on the level, which, should it exceed in amount that which could be melted during the summer, would in time fill the valleys.

This suggests the further question whether were the valleys so filled there would be sufficient weight in the mass to give rise to glacial motion. A partial answer seems to be found in the small glaciers separated by Mt. Muir from the Sierra Nevada near the Yosemite Valley, which "have the structure and motion of true glaciers, but the largest is not more than a mile in length, and they vary in width from half a mile to a few feet." Some of those are therefore certainly smaller than the smallest indicated in this vicinity. Further information along this line would, however, be very desirable.

G. H. SQUIER.

STUDIES FOR STUDENTS.

THE METHOD OF MULTIPLE WORKING HYPOTHESES.[1]

THERE are two fundamental modes of study. The one is an attempt to follow by close imitation the processes of previous thinkers and to acquire the results of their investigations by memorizing. It is study of a merely secondary, imitative, or acquisitive nature. In the other mode the effort is to think independently, or at least individually. It is primary or creative study. The endeavor is to discover new truth or to make a new combination of truth or at least to develop by one's own effort an individualized assemblage of truth. The endeavor is to think for one's self, whether the thinking lies wholly in the fields of previous thought or not. It is not necessary to this mode of study that the subject-matter should be new. Old material may be reworked. But it is essential that the process of thought and its results be individual and independent, not the mere following of previous lines of thought ending in predetermined results. The demonstration of a problem in Euclid precisely as laid down is an illustration of the former; the demonstration of the same proposition by a method of one's own or in a manner distinctively individual is an illustration of the latter, both lying entirely within the realm of the known and old.

Creative study however finds its largest application in those subjects in which, while much is known, more remains to be learned. The geological field is preëminently full of such sub-

[1] A paper on this subject was read before the Society of Western Naturalists in 1892, and was published in a scientific periodical. Inquiries for the article have recently been such as to lead to the belief that a revision and republication are desirable. The article has been freely altered and abbreviated so as to limit it to aspects related to geological study.

jects, indeed it presents few of any other class. There is probably no field of thought which is not sufficiently rich in such subjects to give full play to investigative modes of study.

Three phases of mental procedure have been prominent in the history of intellectual evolution thus far. What additional phases may be in store for us in the evolutions of the future it may not be prudent to attempt to forecast. These three phases may be styled the method of the ruling theory, the method of the working hypothesis, and the method of multiple working hypotheses.

In the earlier days of intellectual development the sphere of knowledge was limited and could be brought much more nearly than now within the compass of a single individual. As a natural result those who then assumed to be wise men, or aspired to be thought so, felt the need of knowing, or at least seeming to know, all that was known, as a justification of their claims. So also as a natural counterpart there grew up an expectancy on the part of the multitude that the wise and the learned would explain whatever new thing presented itself. Thus pride and ambition on the one side and expectancy on the other joined hands in developing the putative all-wise man whose knowledge boxed the compass and whose acumen found an explanation for every new puzzle which presented itself. Although the pretended compassing of the entire horizon of knowledge has long since become an abandoned affectation, it has left its representatives in certain intellectual predilections. As in the earlier days, so still, it is a too frequent habit to hastily conjure up an explanation for every new phenomenon that presents itself. Interpretation leaves its proper place at the end of the intellectual procession and rushes to the forefront. Too often a theory is promptly born and evidence hunted up to fit in afterward. Laudable as the effort at explanation is in its proper place, it is an almost certain source of confusion and error when it runs before a serious inquiry into the phenomenon itself. A strenuous endeavor to find out precisely what the phenomenon really is should take the lead and crowd back the question, commend-

able at a later stage, "How came this so?" First the full facts, then the interpretation thereof, is the normal order.

The habit of precipitate explanation leads rapidly on to the birth of general theories.[1] When once an explanation or special theory has been offered for a given phenomenon, self-consistency prompts to the offering of the same explanation or theory for like phenomena when they present themselves and there is soon developed a general theory explanatory of a large class of phenomena similar to the original one. In support of the general theory there may not be any further evidence or investigation than was involved in the first hasty conclusion. But the repetition of its application to new phenomena, though of the same kind, leads the mind insidiously into the delusion that the theory has been strengthened by additional facts. A thousand applications of the supposed principle of levity to the explanation of ascending bodies brought no increase of evidence that it was the true theory of the phenomena, but it doubtless created the impression in the minds of ancient physical philosophers that it did, for so many additional facts seemed to harmonize with it.

For a time these hastily born theories are likely to be held in a tentative way with some measure of candor or at least some self-illusion of candor. With this tentative spirit and measurable candor, the mind satisfies its moral sense and deceives itself with the thought that it is proceeding cautiously and impartially toward the goal of ultimate truth. It fails to recognize that no amount of provisional holding of a theory, no amount of application of the theory, so long as the study lacks in incisiveness and exhaustiveness, justifies an ultimate conviction. It is not the slowness with which conclusions are arrived at that should give satisfaction to the moral sense, but the precision, the completeness and the impartiality of the investigation.

[1] I use the term theory here instead of hypothesis because the latter is associated with a better controlled and more circumspect habit of the mind. This restrained habit leads to the use of the less assertive term hypothesis, while the mind in the habit here sketched more often believes itself to have reached the higher ground of a theory and more often employs the term theory. Historically also I believe the word theory was the term commonly used at the time this method was predominant.

It is in this tentative stage that the affections enter with their blinding influence. Love was long since discerned to be blind and what is true in the personal realm is measurably true in the intellectual realm. Important as the intellectual affections are as stimuli and as rewards, they are nevertheless dangerous factors in research. All too often they put under strain the integrity of the intellectual processes. The moment one has offered an original explanation for a phenomenon which seems satisfactory, that moment affection for his intellectual child springs into existence, and as the explanation grows into a definite theory his parental affections cluster about his offspring and it grows more and more dear to him. While he persuades himself that he holds it still as tentative, it is none the less lovingly tentative and not impartially and indifferently tentative. So soon as this parental affection takes possession of the mind, there is apt to be a rapid passage to the unreserved adoption of the theory. There is then imminent danger of an unconscious selection and of a magnifying of phenomena that fall into harmony with the theory and support it and an unconscious neglect of phenomena that fail of coincidence. The mind lingers with pleasure upon the facts that fall happily into the embrace of the theory, and feels a natural coldness toward those that assume a refractory attitude. Instinctively there is a special searching-out of phenomena that support it, for the mind is led by its desires. There springs up also unwittingly a pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory. When these biasing tendencies set in, the mind rapidly degenerates into the partiality of paternalism. The search for facts, the observation of phenomena and their interpretation are all dominated by affection for the favored theory until it appears to its author or its advocate to have been overwhelmingly established. The theory then rapidly rises to a position of control in the processes of the mind and observation, induction and interpretation are guided by it. From an unduly favored child it readily grows to be a master and leads its author whithersoever it will. The subsequent history of that mind in respect to that

theme is but the progressive dominance of a ruling idea. Briefly summed up, the evolution is this: a premature explanation passes first into a tentative theory, then into an adopted theory, and lastly into a ruling theory.

When this last stage has been reached, unless the theory happens perchance to be the true one, all hope of the best results is gone. To be sure truth may be brought forth by an investigator dominated by a false ruling idea. His very errors may indeed stimulate investigation on the part of others. But the condition is scarcely the less unfortunate.

As previously implied, the method of the ruling theory occupied a chief place during the infancy of investigation. It is an expression of a more or less infantile condition of the mind. I believe it is an accepted generalization that in the earlier stages of development the feelings and impulses are relatively stronger than in later stages.

Unfortunately the method did not wholly pass away with the infancy of investigation. It has lingered on, and reappears in not a few individual instances at the present time. It finds illustration in quarters where its dominance is quite unsuspected by those most concerned.

The defects of the method are obvious and its errors grave If one were to name the central psychological fault, it might be stated as the admission of intellectual affection to the place that should be dominated by impartial, intellectual rectitude alone.

So long as intellectual interest dealt chiefly with the intangible, so long it was possible for this habit of thought to survive and to maintain its dominance, because the phenomena themselves, being largely subjective, were plastic in the hands of the ruling idea; but so soon as investigation turned itself earnestly to an inquiry into natural phenomena whose manifestations are tangible, whose properties are inflexible, and whose laws are rigorous, the defects of the method became manifest and an effort at reformation ensued. The first great endeavor was repressive. The advocates of reform insisted that

theorizing should be restrained and the simple determination of facts should take its place. The effort was to make scientific study statistical instead of causal. Because theorizing in narrow lines had led to manifest evils theorizing was to be condemned. The reformation urged was not the proper control and utilization of theoretical effort but its suppression. We do not need to go backward more than a very few decades to find ourselves in the midst of this attempted reformation. Its weakness lay in its narrowness and its restrictiveness. There is no nobler aspiration of the human intellect than the desire to compass the causes of things. The disposition to find explanations and to develop theories is laudable in itself. It is only its ill-placed use and its abuse that are reprehensible. The vitality of study quickly disappears when the object sought is a mere collocation of unmeaning facts.

The inefficiency of this simply repressive reformation becoming apparent, improvement was sought in the method of the working hypothesis. This has been affirmed to be *the* scientific method. But it is rash to assume that any method is *the* method, at least that it is the ultimate method. The working hypothesis differs from the ruling theory in that it is used as a means of determining facts rather than as a proposition to be established. It has for its chief function the suggestion and guidance of lines of inquiry; the inquiry being made, not for the sake of the hypothesis, but for the sake of the facts and their elucidation. The hypothesis is a mode rather than an end. Under the ruling theory, the stimulus is directed to the finding of facts for the support of the theory. Under the working hypothesis, the facts are sought for the purpose of ultimate induction and demonstration, the hypothesis being but a means for the more ready development of facts and their relations.

It will be observed that the distinction is not such as to prevent a working hypothesis from gliding with the utmost ease into a ruling theory. Affection may as easily cling about a beloved intellectual child when named an hypothesis as if named a theory, and its establishment in the one guise may

become a ruling passion very much as in the other. The historical antecedents and the moral atmosphere associated with the working hypothesis lend some good influence however toward the preservation of its integrity.

Conscientiously followed, the method of the working hypothesis is an incalculable advance upon the method of the ruling theory; but it has some serious defects. One of these takes concrete form, as just noted, in the ease with which the hypothesis becomes a controlling idea. To avoid this grave danger, the method of multiple working hypotheses is urged. It differs from the simple working hypothesis in that it distributes the effort and divides the affections. It is thus in some measure protected against the radical defect of the two other methods. In developing the multiple hypotheses, the effort is to bring up into view every rational explanation of the phenomenon in hand and to develop every tenable hypothesis relative to its nature, cause or origin, and to give to all of these as impartially as possible a working form and a due place in the investigation. The investigator thus becomes the parent of a family of hypotheses; and by his parental relations to all is morally forbidden to fasten his affections unduly upon any one. In the very nature of the case, the chief danger that springs from affection is counteracted. Where some of the hypotheses have been already proposed and used, while others are the investigator's own creation. a natural difficulty arises, but the right use of the method requires the impartial adoption of all alike into the working family. The investigator thus at the outset puts himself in cordial sympathy and in parental relations (of adoption, if not of authorship,) with every hypothesis that is at all applicable to the case under investigation. Having thus neutralized so far as may be the partialities of his emotional nature, he proceeds with a certain natural and enforced erectness of mental attitude to the inquiry, knowing well that some of his intellectual children (by birth or adoption) must needs perish before maturity, but yet with the hope that several of them may survive the ordeal of crucial research, since it often proves in the end that several agencies were con-

joined in the production of the phenomena. Honors must often be divided between hypotheses. One of the superiorities of multiple hypotheses as a working mode lies just here. In following a single hypothesis the mind is biased by the presumptions of its method toward a single explanatory conception. But an adequate explanation often involves the coördination of several causes. This is especially true when the research deals with a class of complicated phenomena naturally associated, but not necessarily of the same origin and nature, as for example the Basement Complex or the Pleistocene drift. Several agencies may participate not only but their proportions and importance may vary from instance to instance in the same field. The true explanation is therefore necessarily complex, and the elements of the complex are constantly varying. Such distributive explanations of phenomena are especially contemplated and encouraged by the method of multiple hypotheses and constitute one of its chief merits. For many reasons we are prone to refer phenomena to a single cause. It naturally follows that when we find an effective agency present, we are predisposed to be satisfied therewith. We are thus easily led to stop short of full results, sometimes short of the chief factors. The factor we find may not even be the dominant one, much less the full complement of agencies engaged in the accomplishment of the total phenomena under inquiry. The mooted question of the origin of the Great Lake basins may serve as an illustration. Several hypotheses have been urged by as many different students of the problem as the cause of these great excavations. All of these have been pressed with great force and with an admirable array of facts. Up to a certain point we are compelled to go with each advocate. It is practically demonstrable that these basins were river valleys antecedent to the glacial incursion. It is equally demonstrable that there was a blocking up of outlets. We must conclude then that the present basins owe their origin in part to the preëxistence of river valleys and to the blocking up of their outlets by drift. That there is a temptation to rest here, the history of the question shows. But

on the other hand it is demonstrable that these basins were occupied by great lobes of ice and were important channels of glacial movement. The leeward drift shows much material derived from their bottoms. We cannot therefore refuse assent to the doctrine that the basins owe something to glacial excavation. Still again it has been urged that the earth's crust beneath these basins was flexed downward by the weight of the ice load and contracted by its low temperature and that the basins owe something to crustal deformation. This third cause tallies with certain features not readily explained by the others. And still it is doubtful whether all these combined constitute an adequate explanation of the phenomena. Certain it is, at least, that the measure of participation of each must be determined before a satisfactory elucidation can be reached. The full solution therefore involves not only the recognition of multiple participation but an estimate of the measure and mode of each participation. For this the simultaneous use of a full staff of working hypotheses is demanded. The method of the single working hypothesis or the predominant working hypothesis is incompetent.

In practice it is not always possible to give all hypotheses like places nor does the method contemplate precisely equable treatment. In forming specific plans for field, office or laboratory work it may often be necessary to follow the lines of inquiry suggested by some one hypothesis, rather than those of another. The favored hypothesis may derive some advantage therefrom or go to an earlier death as the case may be, but this is rather a matter of executive detail than of principle.

A special merit of the use of a full staff of hypotheses coördinately is that in the very nature of the case it invites thoroughness. The value of a working hypothesis lies largely in the significance it gives to phenomena which might otherwise be meaningless and in the new lines of inquiry which spring from the suggestions called forth by the significance thus disclosed. Facts that are trivial in themselves are brought forth into importance by the revelation of their bearings upon the hypothesis and the elucidation sought through the hypothesis. The phe-

nomenal influence which the Darwinian hypothesis has exerted upon the investigations of the past two decades is a monumental illustration. But while a single working hypothesis may lead investigation very effectively along a given line, it may in that very fact invite the neglect of other lines equally important. Very many biologists would doubtless be disposed today to cite the hypothesis of natural selection, extraordinary as its influence for good has been, as an illustration of this. While inquiry is thus promoted in certain quarters, the lack of balance and completeness gives unsymmetrical and imperfect results. But if on the contrary all rational hypotheses bearing on a subject are worked coördinately, thoroughness, equipoise, and symmetry are the presumptive results in the very nature of the case.

In the use of the multiple method, the reaction of one hypothesis upon another tends to amplify the recognized scope of each. Every hypothesis is quite sure to call forth into clear recognition new or neglected aspects of the phenomena in its own interests, but ofttimes these are found to be important contributions to the full deployment of other hypotheses. The eloquent expositions of "prophetic" characters at the hands of Agassiz were profoundly suggestive and helpful in the explication of "undifferentiated" types in the hand of the evolutionary theory.

So also the mutual conflicts of hypotheses whet the discriminative edge of each. The keenness of the analytic process advocates the closeness of differentiating criteria, and the sharpness of discrimination is promoted by the coördinate working of several competitive hypotheses.

Fertility in processes is also a natural sequence. Each hypothesis suggests its own criteria, its own means of proof, its own method of developing the truth; and if a group of hypotheses encompass the subject on all sides, the total outcome of means and of methods is full and rich.

The loyal pursuit of the method for a period of years leads to certain distinctive habits of mind which deserve more than the passing notice which alone can be given them here. As a

factor in education the disciplinary value of the method is one of prime importance. When faithfully followed for a sufficient time, it develops a mode of thought of its own kind which may be designated the habit of parallel thought, or of complex thought. It is contra-distinguished from the linear order of thought which is necessarily cultivated in language and mathematics because their modes are linear and successive. The procedure is complex and largely simultaneously complex. The mind appears to become possessed of the power of simultaneous vision from different points of view. The power of viewing phenomena analytically and synthetically at the same time appears to be gained. It is not altogether unlike the intellectual procedure in the study of a landscape. From every quarter of the broad area of the landscape there come into the mind myriads of lines of potential intelligence which are received and coördinated simultaneously producing a complex impression which is recorded and studied directly in its complexity. If the landscape is to be delineated in language it must be taken part by part in linear succession.

Over against the great value of this power of thinking in complexes there is an unavoidable disadvantage. No good thing is without its drawbacks. It is obvious upon studious consideration that a complex or parallel method of thought cannot be rendered into verbal expression directly and immediately as it takes place. We cannot put into words more than a single line of thought at the same time, and even in that the order of expression must be conformed to the idiosyncrasies of the language. Moreover the rate must be incalculably slower than the mental process. When the habit of complex or parallel thought is not highly developed there is usually a leading line of thought to which the others are subordinate. Following this leading line the difficulty of expression does not rise to serious proportions. But when the method of simultaneous mental action along different lines is so highly developed that the thoughts running in different channels are nearly equivalent, there is an obvious embarrassment in making a selection for

verbal expression and there arises a disinclination to make the attempt. Furthermore the impossibility of expressing the mental operation in words leads to their disuse in the silent processes of thought and hence words and thoughts lose that close association which they are accustomed to maintain with those whose silent as well as spoken thoughts predominantly run in linear verbal courses. There is therefore a certain predisposition on the part of the practitioner of this method to taciturnity. The remedy obviously lies in coördinate literary work.

An infelicity also seems to attend the use of the method with young students. It is far easier, and apparently in general more interesting, for those of limited training and maturity to accept a simple interpretation or a single theory and to give it wide application, than to recognize several concurrent factors and to evaluate these as the true elucidation often requires. Recalling again for illustration the problem of the Great Lake basins, it is more to the immature taste to be taught that these were scooped out by the mighty power of the great glaciers than to be urged to conceive of three or more great agencies working successively in part and simultaneously in part and to endeavor to estimate the fraction of the total results which was accomplished by each of these agencies. The complex and the quantitative do not fascinate the young student as they do the veteran investigator.

The studies of the geologist are peculiarly complex. It is rare that his problem is a simple unitary phenomenon explicable by a single simple cause. Even when it happens to be so in a given instance, or at a given stage of work, the subject is quite sure, if pursued broadly, to grade into some complication or undergo some transition. He must therefore ever be on the alert for mutations and for the insidious entrance of new factors. If therefore there are any advantages in any field in being armed with a full panoply of working hypotheses and in habitually employing them, it is doubtless the field of the geologist.

T. C. CHAMBERLIN.

EDITORIAL.

THE laudable efforts of the Russian geologists to make the proceedings of the seventh session of the International Geological Congress contribute materially to the advancement of the science along the lines of unification and reformation of classifications and nomenclatures met with but partial success. The number of papers presented that bore directly on these problems was not large and their magnitude was inconsiderable. Nevertheless it will appear in the future that the effort was much more fruitful than seemed at the time to be the case. The results in connection with the classification and nomenclature of stratified formations were more immediate and satisfactory than those relating to the same problems in petrography. Messrs. Frech and Bittner prepared papers that led to the formulation by Messrs. Karpinsky and Tschernyschew of definite propositions for the establishment of principles upon which may be based rules for the creation and use of stratigraphical terms. These were discussed by the congress and agreed to in part. A new committee was appointed to consider the principles of chronological classification of sedimentary formations. The committee consists of active members and of consulting members. The former are: Messrs. Barrois, Capellini, Hughes, Renevier, Tietze, Tschernyschew, H. S. Williams, Zittel. Consulting members are: Choffat, Clark, Cortazar, Davy, Dawson, Déperet, Frech, Griesbach, Karpinsky, Kayser, de Lapparent, Martin, Mayer-Eymar, Nathorst, Nikitin, Stefanescu, De-Stefani, Taramelli, Uhlig, Van der Broeck, Walcott, Woodward.

***

The results in connection with the problem of the reformation of petrographic nomenclature were most disappointing to the

Russian geologists, partly by reason of the fewness of the papers contributed and partly because of the resolution passed by the petrographers present that the time had not arrived for the determination of general principles for the classification and nomenclature of rocks. This, together with the absence of any report from the committee appointed at the sixth session of the congress prevented a discussion of principles and appeared to be a direct reproof of the geologists who had suggested the discussion. It should not be so considered. It was in fact an indication of the wide divergence of opinion on the subject of classification and nomenclature among petrologists and of the consciousness of the rapid changes that are taking place in our knowledge of the elements involved, which would render hasty deliberation fruitless. But there is no question that had a report been presented by the committee it would have elicited a most vigorous discussion. It is to be remarked also that an effort on the part of the petrologists to replace the former committee by a more active one was voted down by the help of those geologists who appeared most anxious to have the problem advanced. The undertaking is of such a serious nature that few cared to offer new suggestions without very careful consideration. Nevertheless the agitation will undoubtedly prove beneficial, and as great advances could be recognized to have taken place since the meeting of the sixth session at Zürich, still greater ones may be expected by the time of the Paris meeting, when it is hoped that the committee will present a report which may not only form the basis for discussion but a foundation for permanent reforms. J. P. I.

Reviews.

The Glacial Lake Agassiz. By Warren Upham. Monograph of the United States Geological Survey, Washington, D. C., 1895.

This *opus magnum* of one of our most active and worthy glacialists has fallen between the two horns of a dilemma common enough in the experience of the busy editor who hesitates between the hasty sketch which alone time permits him to prepare and the careful review which he knows he ought to prepare in due respect for the merits of the work. The choice of the latter which best suits the stress of the hour too often proves but a renewal of the dilemma with added intensity when he next recurs to the subject, and so the struggle goes on until the alternative narrows to an inadequate notice or an unworthy negligence of a work of merit.

This monograph of more than 650 pages, amply illustrated by maps and diagrams, represents several years of very industrious study of the surficial phenomena of the basin of the Red River of the north and adjacent territory, begun under the auspices of the Minnesota Survey and finished under those of the United States Survey with the coöperation of the Canadian Survey.

The treatment is systematic and detailed. Beginning with a general introduction it passes to the topography of the basin which is minutely described, after which the underlying formations embracing the Archæan, the two Silurians, and the Cretaceous, are discussed at some length. The glacial period and its drift deposits are treated with still more fullness because of their immediate relations to the history of Lake Aggasiz. This is introduced by a review of the glacial period in North America, and a comprehensive sketch of the continental ice-sheet which is illustrated by an excellent map showing not only the general distribution of North American Pleistocene glaciation as known at the time of its preparation, but also the directions of movement in various parts of the great area. Greenland

and the Archipelago north of the continent are included. The Laurentide and Cordilleran ice-sheets are differentiated and the debatable belt between them indicated. The Keewatin ice-sheet which has since been differentiated from the Laurentide glacier in part at least by Tyrrell is, of course, not separately represented. The recession of the ice-sheet and the courses of the ice movement in the immediate vicinity of Lake Agassiz are very fully set forth, as well as the drift deposits of the region. The succession of terminal moraines is amply delineated by text and maps. The moraines from the seventh or Dovre to the eleventh or Mesabi are regarded as contemporaneous with Lake Agassiz.

With this very ample but needful introduction the history of Lake Agassiz is delineated. A distinction is drawn between the Great Basin lakes, Bonneville, Lahontan, and others, and true glacial lakes of the Agassiz type. The indubitable evidences of the existence of the lake in a well-cut outlet, eroded cliffs, beaches, deltas, and lacustrine deposits, are set forth in general terms at the outset and taken up in much detail afterwards.

The contemporaneity of the great ice-sheet and the dependence of the lake upon the ice mass for its northern barrier is a central point of interest in the monograph. The changes in the history of the lake are made dependent upon the shifting position of this ice barrier, upon the erosion of the outlet, and upon progressive changes in the earth's surface. An attempt is made to measure the duration of Lake Agassiz by means of its beaches, its moraines, and correlated phenomena, with the result that the period is believed to have been short and the formation of the moraines very rapid. Some alternative interpretations by Chamberlin, under whose direction the work was prosecuted, are introduced at this point at the request of the author, the chief purport of which is to assign a series of rising as well as falling stages to the shores of Lake Agassiz and to thereby make the moraines antedate the highest beach and to leave the time occupied in their formation undetermined.

The beaches are divided into two classes, the one set being those connected with the southern outlet at Lake Traverse and the other set those connected with some undetermined outlet to the northward. Five distinct stages, represented by as many beaches or groups of beaches, belong to the first set and four to the second. One of the most important features of the monograph is the accurate determina-

tion of very notable changes in the level of these beaches. A former relative rise of the surface to the northeast is not only amply demonstrated, but a progressive fall of the surface at the north at later stages until it reached its present attitude is fully made out. The movement appears to have been steadily progressive and systematic. The possible causes of these changes of levels are discussed, embracing gravitation toward the ice-sheet which, while measurably effective, is found quantitatively insufficient, changes in the temperature of the earth's crust which is also regarded as insufficient, and epeirogenic movements apparently dependent in part upon glaciation, which is regarded as the essential agency. In this connection the author extends his discussion widely, treating of the preglacial elevation of North America, as shown by fiords and submarine valleys and of the late glacial or Champlain submergence shown by fossiliferous marine beds overlying glacial deposits, and from these he endeavors to deduce the Pleistocene oscillations embracing those which were independent of glaciation as well as those dependent upon it. He maintains his well-known views regarding the dependence of glaciation essentially upon epeirogenic movements.

The monograph closes with chapters on the artesian and common wells of the Red River valley and the agricultural and mineral resources of the area of Lake Agassiz. There are added appendices giving the courses of glacial striæ and notes on aboriginal earth works within or near the area of the lake. The whole material is worked out with care and great detail and constitutes a very important contribution to Pleistocene history in both its glacial and its lacustrine aspects. T. C. C.

Catalogue of the Tertiary Mollusca in the Department of Geology, British Museum (Natural History). Part I. The Australasian Tertiary Mollusca. By GEORGE F. HARRIS, F.G.S. 407 pp., 8 pls. London, 1897.

The British Museum, which has in process of publication catalogues of its great collections, has lately started a new series upon the Tertiary Mollusca, under the editorship of Professor Harris. The first volume dealing with the Australasian forms has just made its appearance. The acquisition by the Museum at different times since

1860 of large numbers of Teritary mollusca from Australia and New Zealand, has made it possible for Professor Harris to present a very exhaustive review of the subject, the Gasteropoda particularly being described in great detail. The fine state of preservation of the specimens has led the author to consider the several forms both from an ontogenetic and phylogenetic standpoint, and as so little work of this character has been done on the Gasteropoda, hitherto, it must prove of fundamental importance in the systematic classification of this class of the mollusca.

The book contains a complete synonomy of all the forms catalogued, together with a description of such new material as the Museum possesses. The admirable figures which accompany the volume show in great detail the protoconchs of many of the Gasteropod types.

This report presents the first thoroughly systematic treatment of the Tertiary molluscan faunas of Australasia and will be of great service to the student of Tertiary mollusca in other portions of the world. Volume I will be succeeded by others in which the large Tertiary collections of the British Museum from other lands will be minutely described. There is no man better able to undertake this task than Professor Harris, as he is intimately acquainted with the Tertiary in many portions of the world, and probably has a more comprehensive knowledge of the Tertiary of central and western Europe than any one living. He has published an important memoir on the Eocene geology and palæontology of the Paris Basin, besides making contributions to the Tertiary of England.

The future publications of this series will be awaited with much interest by all students of Tertiary palæontology.

WM. B. CLARK.

Transactions of the American Institute of Mining Engineers, Vol. XXVI. February 1896, to October 1896 inclusive. Published by the Institute, New York City, 1897.

This number of the *Transactions* presents a goodly list of papers of especial interest to geologists. Of these we may mention the following:

The Ore Deposits of the Australian Broken Hill Consols Mine, Broken Hill, New South Wales. By GEORGE SMITH, pp. 69-78. This

is an interesting discussion on the concentration of dyscrasite and antimonial silver chloride where the lode is cut by cross veins or "*indicators*." The author finds it necessary to invoke the aid of the electro-magnetic currents of the earth's crust acting along the cross veins to account for this particular form of deposition.

Copper Ores in the Permian of Texas. By E. J. SCHMITZ, JR., pp. 97-108 (discussion p. 1051). The copper ores of the Texas Permian occur as pseudomorphs of wood or as nodules or copper-bearing shale, slate or clay, and was deposited under much the same conditions as the "*Hupperschiefer*" in the German Permian, the chief difference being that the American ore is in the main a carbonate or silicate, while the German is a sulphide.

Vein Walls. By T. A. RICKARD, pp. 193-241 (discussion p. 1153). A valuable dissertation upon the relation of ore deposition to the composition and structure of the inclosing strata.

Sketch of a Portion of the Gunnison Gold Belt, Including the Vulcan and Mammoth Chimney Mines. By ARTHUR LAKES, pp 440-448.

Gold in Granite and Plutonic Rocks. By WILLIAM P. BLAKE, pp. 290-298. A summary of a number instances of the occurrence of gold as a primary constituent of granite and plutonic rocks.

Faulting and Accompanying Features Observed in Glacial Gravel and Sand in Southern Michigan. By CARL HENRICH, pp. 460-464 (discussion p. 1102). The faulting occurs in stratified gravel. The fault planes are from seven to twelve feet apart, and none have a throw of less than seven inches. Along these fault planes nodules have been formed by *ascending* currents of water. The explanation offered is that lateral pressure was caused by two glaciers converging along Silver Creek and Goose Greek valleys.

Further Notes on the Alabama and Georgia Gold-Fields. By WILLIAM H. BREWER, pp. 464-472.

The Ore-Shoots of Cripple Creek, Colorado. By EDWARD SKEWES, pp. 553–579. A detailed description of the ore-shoots of a portion of the Cripple Creek district, and their relations to the vein fissures.

Traces of Organic Remains from the Huronian (?) Series at the Iron Mountain, Michigan, etc. By W. S. GREESLEY, pp. 527-534. An account of the author's discovery of certain markings on the iron ore

upon the docks at Erie, Pa. which he indentifies as fossil remains. Three plates follow the article.

The Phosphate Deposits of Arkansas. By JOHN C. BRANNER, pp. 580-598. The phosphate deposits are reported in or associated with a narrow zone either of greenish or black shale, or a sandstone deposited between recognized Lower Silurian and Carboniferous strata. This interval represents the slow accumulation of organic matter in a comparatively deep sea. Phosphate nodules have also been found in some of the Cretaceous beds of the region.

Magnetic Observation in Geological Mapping. By HENRY LLOYD SMITH, pp. 640-709. The principles of plotting magnetic observation and applications to geological mapping, etc.

Some Mines of Rosita and Silver Cliff, Colorado. By S. F. EMMONS, pp. 773-822. The ore of the Bassic mine was deposited by fumoralic action as a phase of the dying activity of the volcano when H_2S and S_2O were the prevailing gases. The Bull-Domingo mine ores were deposited from aqueous solutions coming from a region of igneous eruptions close at hand.

Discussing the composition of descending surface waters and ascending deep waters Mr. Emmons concludes, in opposition to the prevalent belief, that decreasing temperature and pressure are not the principal determining causes of the precipitation of vein minerals from ascending solutions. Also that all the metallic minerals of the plateau were formed under the same conditions and during the same general phase of ore deposition, and their irregular dissemination is due to physical rather than to chemical causes.

He states also that "the heavy metals have probably been brought up from the interior of the earth within the magmas of igneous rocks, and that by some process of differentiation not yet completely understood either previous to, or during the process of cooling and consolidation, they have been concentrated within certain bodies or parts of bodies of eruptive rocks; and, further, that ore bodies as found at the present day are the result of a concentration (perhaps many times repeated) of the materials thus brought up, which are in all probability very finely disseminated through the present rock masses or combined in minute amounts in the more common basic minerals. This seems a more rational hypothesis, and one more in accordance with modern scientific practice, than to content oneself with assuming simply that

the ascending waters came charged with metallic minerals from the bathysphere, meaning thereby a region in the interior of the earth which is richer in heavy metals than any part of the earth's crust that comes under our observation ; for this simple assumption affords no explanation why metallic minerals are concentrated in one part of the earth's crust and not in another, and it supposes a free flow of waters at greater depths than in our present state of knowledge of terrestrial physics it is considered possible that channels which would admit of a flow of water through them would remain open.

" Furthermore, if the vein-materials are found to form a constituent part, even in minute traces, of comparatively fresh and unaltered country-rocks in a given ore-bearing region, and at such distances from any water-channels as to render it improbable that these materials could have been brought in through these channels, it is reasonable to assume that these or similar rocks have been permeated by the waters from which the known ore deposits were precipitated, and that from them they derived their contained vein-materials. . . . . It seems probable that not only the recent eruptives, but the older granites through which the ascending solutions must have passed, contain enough of the precious metals, and, it may be assumed also, of the other vein-materials to furnish, in the long time that is accorded to the accomplishment of most geological phenomena, sufficient material of the formation of existing ore-bodies. The analysis of the vadose waters in the Geyser mine has demonstrated the capability possessed by even cold surface waters of taking up such materials in their passage through the rocks. The subterranean waters that were circulating here at the time of the formation of the ore-deposits must have been much more energetic solvents, being heated by contact with the cooling masses of igneous rock, and probably deriving a certain amount of active and energetic mineralizing agents, such as fluorine, chlorine, etc., from these igneous masses at the time of contact. Hence it is fair to assume that the vein-materials in this region were originally derived from both recent and ancient eruptive rocks —a conclusion similar to that arrived at by Mr. Penrose, from his more exhaustive study of the ore-deposits of Cripple Creek."

The Occurrence and Treatment of Certain Gold Ores of Park County, Colorado. By B. SADTLER, pp. 848–853.

The Occurrence of Gold Ores in the Rainy River District, Ontario, Canada. By WM. H. MERRITT, pp. 853–863.

Other papers — such for example — as *The Microstructure of Steel and the Current Theories of Hardening*, by ALBERT SAUVEUR, have direct application to the broad domin of theoretical geology.

C. F. TOLMAN JR.

The Law of Mines and Mining in the United States. By DANIEL MOREAU BARRINGER and JOHN STOKES ADAMS. Little, Brown, & Co., Boston, 1897.

Although primarily a legal work this book possesses not a little interest and value to geologists in general and especially to those who have to deal with economic interests. It opens with a geological preface in which the various kinds of mineral deposits that are liable to be subjects of litigation are defined and their modes of occurrence and to some extent their origins are briefly stated, as these features are often decisive in the legal classification of the formations. The purpose of the work is to give a better appreciation of the reasons for the established legal distinctions relative to mineral deposits, insofar as these are based on differences in the nature, the mode of occurrence or the origin of the deposits. While the matter is not new to geologists and makes no pretension to exhaustiveness, its special point of view gives not a little freshness to the sketch. The legal classification of ore deposits is not without its suggestiveness to scientific students.

The body of the book opens with a chapter on property in minerals where there has been no division between the ownership of the surface and of the mineral below, followed by one on property rights where the title to the mineral or the right to take it out is vested in some one who is not the owner of the soil. It then treats of mineral leases and the rights and duties arising thereunder, and the modes of assignment and termination of leases. Chapters follow on the property of the sovereign and its grantees in minerals, for example, minerals in the beds of navigable streams or under public highways or in lands taken by eminent domain. There is also a discussion of the government's title and the granting thereof. A chapter is devoted to the discovery and location of claims, another to the extent of claims, and one each to the method by which claims are held, to the local mining rules and regulations, to the method by which title to mining claims may be terminated, and to the reloca-

tion of claims; also one each to the acquiring of a title before the patent and to the patent itself. The different kinds of claims, as lode claims, placer claims, lodes in placers, tunnel claims, mill sites and water right claims are systematically treated. Passing by some chapters on special themes we may note those on the rights of mine owners and of miners respectively, and the one on the application of equitable principles and remedies to mining operations. An appendix embraces the United States statutes relative to mineral deposits and the land office regulations. A very large number of cases are cited and briefly abstracted in illustration of the general treatment of the several themes. T. C. C.

The Science of Brickmaking: with some Account of the Structure and Physical Properties of Bricks. By GEORGE F. HARRIS, F.G.S. 160 pp. H. Greville Montgomery, London, 1897.

Professor Harris has presented in this little volume an admirable elementary treatise upon the science of brickmaking, which cannot fail to be of much value to the more intelligent class of brickmakers and clayworkers generally. The subject is logically and systematically discussed and is illustrated with a large number of local examples of brick-earths. The book contains much new information upon one of the most important economic subjects with which the geologist comes in touch. It is significant to see a man of Professor Harris' scientific attainments in the more theoretical and technical phases of geology turning his attention to so thoroughly practical a subject as that of brickmaking. Professor Harris rightly thinks that too many geologists do not sufficiently regard the economic aspects of their science, and he is preparing to present to the English-reading public still further contributions upon the practical side of geology.

The book opens with a discussion of the different types of brick-earths, which are classified as fluviatile, lacustrine and fluviatile, and marine. Following this are chapters devoted to the mineral constitution of brick-earths, and the behavior of the various minerals in the kiln. In this connection the author clearly points out that the chemical analysis does not always afford the needed information to the brickmaker, but that the physical constitution of the materials also has great influence in determining the value of the brick-earth.

The chemistry of brick-earths and the methods to be pursued in analyzing them are considered at much length. The micro-structure of bricks is presented in a manner to be of much aid to the practical brickmaker who is anxious to determine the texture of his product. The important question of the durability of bricks is also discussed. Among the tests which are mentioned by the author are the chemical composition of the brick, its absorptive capacity, its minute structure, its specific gravity, and its strength. Each of these subjects is discussed in some detail.

This information cannot but be highly beneficial to the brickmaker capable of appreciating the bearing which accurate scientific knowledge has upon his industry. Similar treatises to that of Professor Harris, with American illustrations, would be of much value to our own economic interests. The more our operators, whether in clay or other mineral products, come to realize their dependence upon scientific fact, and they will only realize it by the geologist interesting himself in their work, the better for the success of their endeavors, and the greater influence the scientific expert will have among practical men generally.

WM. B. CLARK.

Index to Volume V.

PAGE

ABSTRACTS:

Age of the Lower Coals of Henry County, Missouri. David S. White - 218
Age of the White Limestone of Sussex County, New Jersey. J. E. Wolff and A. H. Brooks - - - - - - - - - - - 322
A Study of the Nature, Structure and Phylogeny of Daemonelix. E. H. Barbour - - - - - - - - - - - - - - - 223
Complete Oil-well Record in the McDonald Field between the Pittsburg Coal and the Fifth Oil Sand. I. C. White - - - - - - 103
Cornell Glacier, Greenland. Ralph S. Tarr - - - - - - 95
Crater Lake, Oregon. J. S. Diller - - - - - - - - 219
Crystalline and Metamorphic Rocks of Northwest Georgia. C. Willard Hayes and Alfred H. Brooks - - - - - - - - - 321
Dikes in Appalachian Virginia. N. H. Darton - - - - - 324
Erosion at Base Level. M. R. Campbell - - - - - - - 322
Geological Atlas of the United States, Folio 30, Yellowstone National Park, Wyoming. 1896 - - - - - - - - - - 405
Geological Atlas of the United States, Folio 24, Three Forks, Montana. 1896 - - - - - - - - - - - - - - 407
Geological Atlas of the United States, Folio 29, Nevada City, special folio, California. 1896 - - - - - - - - - - 409
Geological Atlas of the United States, Folio 26, Pocahontas, Virginia–West Virginia. 1896 - - - - - - - - - - - 414
Geological Atlas of the United States, Folio 25, Loudon, Tennessee. 1896 - - - - - - - - - - - - - - 416
Geological Atlas of the United States, Folio 27, Morristown, Tennessee. 1896 - - - - - - - - - - - - - - 417
Glacial Observations in the Umanak District, Greenland. Geo. H. Barton - - - - - - - - - - - - - - - 89
Grain of Rocks. Alfred C. Lane - - - - - - - - - 222
Homology of Joints and Artificial Fractures. J. B. Woodworth - - 97
Leucite Hills of Wyoming. J. F. Kemp - - - - - - - 100
Modified Drift in St. Paul, Minnesota. Warren Upham - - - 111
Nipissing-Mattawa River, the Outlet of the Nipissing Great Lakes. F. B. Taylor - - - - - - - - - - - - - - - 220
Note on the Plasticity of Glacial Ice. Israel C. Russell - - - 104
Notes on Rock Weathering. George P. Merrill - - - - - 98
Notes on the Potsdam and Lower Magnesian Formation of Wisconsin and Minnesota. Joseph F. James - - - - - - - - 99

PAGE

ABSTRACTS:

Old Tracks of Erian Drainage in Western New York. G. K. Gilbert - 109
Origin and Age of the Gypsum Deposits of Kansas. G. P. Grimsley - 94
Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian. Frank D. Adams and Alfred E. Barlow - - 92
Origin of Certain Topographic Forms. M. R. Campbell - - - 323
Physical Nature of the Problem of General Geological Correlation. Charles R. Keyes - - - - - - - - - - - - - 110
Pre-Cambrian Topography of the Eastern Adriondacks. J. F. Kemp - 101
Preliminary Note on the Pleistocene History of Puget Sound. Bailey Willis - - - - - - - - - - - - - - 99
Principal Features of the Geology of Southeastern Washington. Israel C. Russell - - - - - - - - - - - - - 107
Shore Lines of Lake Warren and of a Lower Water Level in Western New York. H. L. Fairchild - - - - - - - - - - 106
Solution of Silica under Atmospheric Conditions. C. W. Hayes - - 319
Stratigraphy and Palæontology of the Laramie and Related Formations in Wyoming. T. W. Stanton and F. H. Knowlton - - - - 102
Unconformities in Martha's Vineyard and Block Island. J. B. Woodworth - - - - - - - - - - - - - - 96
United States Geological Atlas, Folio 28, Piedmont, West Virginia-Maryland, 1896 - - - - - - - - - - - - - 411
United States Geological Atlas, Folio 23, Nomini, Maryland-Virginia. 1896 - - - - - - - - - - - - - - 413
Upper Cretaceous of the Northern Atlantic Coastal Plain. Wm. B. Clark - - - - - - - - - - - - - - 217
Work of the United States Geological Survey in the Sierra Nevada. H. W. Turner - - - - - - - - - - - - - 105
Academy of Natural Sciences, Bulletin of the Minnesota. C. W. Hall. Review by T. C. Chamberlin - - - - - - - - - 648
Academy of Natural Sciences, Proceedings of the Davenport. Review by T. C. Chamberlin - - - - - - - - - - - - - 649
Academy of Sciences, Proceedings of the Iowa. Review by T. C. Chamberlin - - - - - - - - - - - - - - 648
Adams, Frank and Alfred Barlow. Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian. (Abstract) - - 92
Review: Some Recent Papers on the Influence of Granitic Intrusions upon the Development of Crystalline Schists - - - - - 293
Agassiz, Alexander. The Elevated Reef of Florida. Review by J. E. Woodman - - - - - - - - - - - - - - 312
Agassiz, The Glacial Lake. Warren Upham. Review by T. C. Chamberlin - - - - - - - - - - - - - - 750
Alabama, Geological Survey of. E. A. Smith. Report on the Valley Regions. Part II, on the Coosa Valley. H. McCalley. Review by T. C. Chamberlin - - - - - - - - - - - - - - 646
Analcite Basalt from Colorado. Whitman Cross - - - - - - - 684

PAGE

Analyses - - - - - - - 49, 247, 248, 252, 266, 268, 269, 352, 358, 370
Ancient Volcanoes of Great Britain. Archibald Geike. Review by J. P. Iddings - - - - - - - - - - - - - - - - - - 531
Ancient Volcanic Rocks of South Morristown, Pennsylvania. Florence Bascome. Review by J. P. Iddings - - - - - - - - - 213
Andendiorite in Japan. C. Iwasaki - - - - - - - - - - 721
Appalachians across Mississippi, Louisiana, and Texas, The Former Extension of the. J. C. Branner. Review by A. B. Purdue - - - - - 759
Atmosphere - - - - - - - - - - - - - - - - - - - 653
Atwood, Wallace Walter, Rollin D. Salisbury and. Drift Phenomena in Wisconsin - - - - - - - - - - - - - - - - - - 131

Baffins Land, Evidences of Recent Elevation of the Southern Coast of. T. L. Watson - - - - - - - - - - - - - - - - - - 17
Bain, H. Foster. Sketch of the Geology of Mexico - - - - - - - 384
Reviews: Geology of the Castle Mountain Mining District, Montana. W. H. Weed and L. V. Pirsson - - - - - - - - - 210
Missouri Geological Survey. Vol. XI, Clay Deposits. H. A. Wheeler 399
Baltic Glacier, The Last Great. James Geikie - - - - - - - - 325
Bannister, H. M. The Drift and Geologic Time - - - - - - - - 730
Barbour, E. H. Study of the Structure and Phylogeny of Daemonelix. (Abstract) - - - - - - - - - - - - - - - - 223
Barlow, Alfred E., Frank D. Adams and. Origin and Relation of the Grenville and Hastings Series in the Canadian Laurentian. (Abstract) - 92
Barton, Geo. H. Glacial Observations in Greenland. (Abstract) - - - 89
Barton, Geo. H. Glacial Observations in Greenland. Review by T. C. Chamberlin - - - - - - - - - - - - - - - - - - 650
Basalt - 255
Bascom, Florence. Ancient Volcanic Rocks of South Mountain, Pennsylvania. Review by J. P. Iddings - - - - - - - - - - - 213
Bauxite Deposits of Arkansas. J. C. Branner - - - - - - - - 263
Bayley, W. S., C. R. Van Hise and. Preliminary Report on the Marquette Region. Review by U. S. Grant - - - - - - - - - 402
Beaches with Outlets and Moraines in Southeastern Michigan, Correlation of Erie-Huron. F. B. Taylor. Review by C. H. Gordon - - - 313
Becker, G. F. Some Queries on Rock Differentiation. Review by C. F. Tolman, Jr. - - - - - - - - - - - - - - - - - 393
Bedford Oölitic Limestone of Indiana. T. C. Hopkins and C. E. Siebenthal. Review by J. C. Branner - - - - - - - - - - - - 529
Bibbins Arthur, William B. Clark and. The Stratigraphy of the Potomac Group in Maryland - - - - - - - - - - - - - - 479
BIBLIOGRAPHY:
Italian Petrological Sketches, 34; of Crystalline Schists, 293; of influence of Granitic Intrusion upon the development of Recent Elevations in North America, Partial, 32; of the Bauxite, 285; of the Lower Cretaceous - - - - - - - - - - - - - - - - 610

PAGE

BIBLIOGRAPHY: Recent Publications - - - - - - 224, 419, 535, 761
Biotite-Vulsinite - - - - - - - - - - - - - - 250
Blatchley, W. S. Geology and Natural Resources of Indiana. Review by T. C. Chamberlin - - - - - - - - - - - - - - 644
Bowlder Clays of the Great Plains Marine? Are the. Geo. M. Dawson - 257
Bracciano Region - - - - - - - - - - - - - - 35
Branner, J. C. The Bauxite Deposits of Arkansas - - - - - - - 263
Reviews: Bedford Oölitic Limestone of Indiana. T. C. Hopkins and C. E. Siebenthal - - - - - - - - - - - - - 529
Devonian Fauna in the Reo Maccarú. F. Katser - - - - - 757
Former Extension of the Appalachians across Mississippi and Texas. Review by A. H. Purdue - - - - - - - - - - 759
Unpublished Papers of the Geological Survey of Brazil - - - - 756
Brazil, Unpublished Papers of the Geological Survey of. Review by J. C. Branner - - - - - - - - - - - - - - 756
Brickmaking, the Science of. F. G. Harris. Review by Wm. B. Clark - - 658
Brooks, A. H., and J. E. Wolff. The Age of the White Limestone of Sussex County, New Jersey - - - - - - - - - - - - 322
Brooks, A. H., C. W. Hayes and. Crystalline and Metamorphic Rocks of Northwestern Georgia. (Abstract) - - - - - - - - - 321
Brush, Geo. J. Manual of Determinative Mineralogy. Review by O. C. Farrington - - - - - - - - - - - - - - - 86
Bulletins of American Palæontology, Vol. I. G. D. Harris. Review by Stuart Weller - - - - - - - - - - - - - - - 309
Bulletins of the Minnesota Academy on Natural Sciences. Vol. IV, No. 1, Pt. I. Proceedings and Accompanying Papers. Review by T. C. Chamberlin - - - - - - - - - - - - - - 648

California and Lower California, The Submerged Valleys of. Geo. Davidson. Review by W. S. Tangier Smith - - - - - - - - - 533
California at the Typical Locality, The Geological Relations of the Martinez Group of. John C. Merriam - - - - - - - - - - 767
California, The Topography of. Noah Fields Drake - - - - - - 563
Calvin, S. Iowa Geological Survey. Review by T. C. Chamberlin - - 642
Campbell, M. R. Erosion at Base Level. (Abstract) - - - - - - 322
Origin of Certain Topographic Forms - - - - - - - - - 323
Canada, Geological Survey of. Annual Report. G. M. Dawson. Review by T. C. Chamberlin - - - - - - - - - - - - - 641
Cape of Good Hope, First Report of the Geological Commission of the Colony of the. Review by T. C. Chamberlin - - - - - - - - 647
Carbon Dioxide - - - - - - - - - - - - - - - 677
Carboniferous and Permian Formations of Kansas and Nebraska, Comparison of. Charles S. Prosser. Part I - - - - - - - - - 1
Part II - - - - - - - - - - - - - - - 148
Castle Mountain Mining District, Geology of the. W. H. Weed and L. V. Pirsson. Review by H. F. Bain - - - - - - - - - 210

PAGE

Catalogue de Bibliographies Geologiques. (Editorial) T. C. C. - - - 199
Catalogue of Tertiary Mollusca. Geo. F. Harris. Review by Wm. B. Clark - 853
Cerveteri Region - - - - - - - - - - - - - - - - 44
Chamberlin, T. C. A Group of Hypotheses Bearing on Climatic Changes - 653
Glacial Studies in Greenland. X - - - - - - - - - 229
Method of Multiple Working Hypotheses - - - - - - - 837
Supplementary Hypotheses Respecting the Origin of Loess of the Mississippi Valley - - - - - - - - - - - - 795
Editorials: Andrée's Expedition - - - - - - - - 525
Catalogue des Bibliographies Geologiques - - - - - - 196
Detroit Meeting of the American Association for the Advancement of Sciences - - - - - - - - - - - - - - 636
Lectures of Dr. Hans Reush - - - - - - - - - 755
The Limit of Greenland Glaciation - - - - - - - - 81
Removal of the Director of the Geological Survey of Missouri - - 527
Reviews: Bulletin of the Minnesota Academy of Natural Sciences - 648
First Report of the Geological Commission of the Colony of the Cape of Good Hope - - - - - - - - - - - - - 647
Former Extension of Cornell Glacier near the Southern End of Melville Bay - - - - - - - - - - - - - - - 303
Geological and Natural Resources of Indiana. W. S. Blatchley - 644
Geological Survey of Alabama. E. A. Smith. Report on the Coosa Valley. H. McCalley - - - - - - - - - - - 646
Geological Survey of Canada. G. M. Dawson - - - - - - 641
Glacial Lake Agassiz. Warren Upham - - - - - - - 851
Glacial Observations in the Umanak District, Greenland. G. H. Barton - - - - - - - - - - - - - - - 650
Glaciers of North America. I. C. Russell - - - - - - - 302
Iowa Geological Survey. S. Calvin - - - - - - - - 642
Laws of Mines and Mining in the United States - - - - - 858
North Carolina and Its Resources - - - - - - - - 648
Proceedings of the Davenport Academy of Natural Sciences - - 649
Proceedings of the Iowa College of Sciences - - - - - - 648
Seventeenth Annual Report of the United States Geological Survey - 651
Stone Implements of the Potomac Chesapeake Tide Water Province. W. H. Holmes - - - - - - - - - - - - - 649
Chase, E. C. Review: Dinosaurs of North America - - - - - - 87
Ciminite - - - - - - - - - - - - - - - - - - 351
Clark, William Bullock, and Arthur Bibbins. The Stratigraphy of the Potomac Group in Maryland - - - - - - - - - - - - 479
Clark, W. B. Cretaceous of the North Atlantic Coastal Plane. (Abstract) - 217
Eocene Deposits of the Middle Atlantic Slope. Review by C. R. Keyes - - - - - - - - - - - - - - - - 310
Maryland Geological Survey. Review by R. D. Salisbury - - - - 760
Reviews: Catalogue of the Tertiary Mollusca. Geo. F. Harris - - 853
Science of Brickmaking. G. F. Harris - - - - - - - 859

PAGE

Clay Deposits Missouri Geological Survey. Vol. XI. H. A. Wheeler. Review by H. F. Bain - - - - - - - - - - - - - 399
Climatic Changes, A Group of Hypotheses Bearing on. T. C. Chamberlin - 653
Colorado, An Analcite Basalt from. Whitman Cross - - - - - - 684
Commission of the Colony of the Cape of Good Hope, First Report of the Geological. Review by T. C. Chamberlin - - - - - - 647
Comparative Study of Palæontology and Phylogeny. (Studies for Students) James Perrin Smith - - - - - - - - - - - - 507
Comparative Study of the Lower Cretaceous Formation and Fauna of the United States. Timothy William Stanton - - - - - - 579
Cornell Glacier near the Southern End of Melville Bay, Former Extension of. Ralph S. Tarr. Review by T. C. C. - - - - - - - - 303
Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan. F. B. Taylor. Review by C. H. Gordon - - - 313
Correlation of the Devonian Faunas in Southern Illinois. Stuart Weller - 625
Cragin, W. F. Discovery of Marine Jurassic Rocks in Southwestern Texas - 813
Cretaceous Formation and Faunas of the United States, A Comparative Study of the Lower. Timothy S. Stanton - - - - - - - - 579
Cripple Creek District Colorado, Geology and Mining Industry of. Whitman Cross, and R. A. F. Penrose, Jr. Review by Arthur Winslow - - 197
Cross, Whitman. An Analcite Basalt from Colorado - - - - - - 684
Cross, Whitman, and R. A. F. Penrose. Geology and Mining Industry of Cripple Creek District. Review by Arthur Winslow - - - - - 197
Cryptodiscus, Hall. Stuart Weller - - - - - - - - - - 803
Crystalline Schists, Some Recent Papers on the Influence of Granite Intrusions Upon the Development of. Review by Frank S. Adams - - - 293

Daly, R. A. Studies on the So-called Porphyritic Gneiss. Part I - - - 694
Part II - - - - - - - - - - - - - - - 776
Darton, N. H. Dikes in Appalachian Virginia. (Abstract) - - - - - 324
Davenport Academy of Natural Sciences, Proceedings of the. Review by T. C. Chamberlin - - - - - - - - - - - - - - 649
Davidson, Geo. The Submerged Valleys of California and Lower California. Review by W. S. T. Smith - - - - - - - - - - 533
Dawson, Geo. M. Are the Bowlder Clays of the Great Plains Marine? - - 257
Geological Survey of Canada. Review by T. C. Chamberlin - - 641
Editorial, Laurentide Glacier - - - - - - - - - - 78
Deformation of Rocks. V (Studies for Students). C. R. Van Hise - - 178
Delaware and Virginia, Eocene Deposits of the Middle Atlantic Slope in Maryland. Wm. Bullock Clark. Review by Chas. R. Keyes - - - 310
Devonian Faunas in Southern Illinois, Correlation of the. Stuart Weller - 625
Devonian Fauna of the Reo Maecurú. F. Katzer. Review by J. C. Branner - 757
Differentiation, Some Queries on. G. F. Becker. Review by C. F. Tolman, Jr. 393
Divides, A Note on the Migration of. W. S. Tangier Smith - - - - 809
Diller, J. S. Crater Lake, Oregon. (Abstract) - - - - - - - 219
Dinosaurs of North America. Othniel Charles Marsh. Review by E. C. Chase 87

PAGE

Discovery of Marine Jurassic Rocks in Southwestern Texas. F. A. Cragin - 831
Drake, Noah Fields. The Typography of California - - - - - - 531
Drift and Geologic Time. H. M. Bannister - - - - - - - - 730
Driftless Region of Wisconsin, Studies in. G. H. Squier - - - - - 825
Drift Phenomena in the Vicinity of Devil's Lake and Baraboo, Wisconsin. Rollin D. Salisbury, Wallace Walter Atwood, and - - - - - 131

Elementary Geology. Ralph S. Tarr. Review by H. B. Kümmel - - - 317
EDITORIALS.
Andrée's Expedition. T. C. C. - - - - - - - - - - 525
Catalogue des Bibliographies Geologiques. T. C. C. - - - - 196
Detroit and Toronto Meetings. T. C. C. - - - - - - - 636
George Huntington Williams Memorial Lectures. J. P. I. - - - 391
International Congress at St. Petersburg. J. P. I. - - - - 290
International Congress upon Classification. J. P. I. - - - - 849
Laurentide Glacier. G. M. D. - - - - - - - - - 78
Lectures of Dr. Hans Reusch. T. C. C. - - - - - - 755
Limit of Greenland Glaciation. T. C. C. - - - - - - - 81
Meeting of the Geological Society of America. J. P. I. - - - 77
Removal of the Director of the Geological Survey of Missouri. T. C. C. 527
Rohn's Collections of Rock Specimens J. P. I. - - - - - 195
Seventh Session of the International Congress of Geologists. J. P. I. - 752
Winter Meetings of the Geological Society of America. I. C. R. - 194
Elevated Reef of Florida. Alexander Agassiz, with Notes on Geology of Southern Florida. Leon S. Griswold. Review by J. Edmund Woodman - - - - - - - - - - - - - - - 312
Elevation of the Southern Coast of Baffin Land, Evidences of Recent. Thomas L. Watson - - - - - - - - - - - - - 17
Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware, and Virginia. Wm. Bullock Clark. Review by Charles R. Keyes - - 310
Eruptive Rocks of Mexico. O. C. Farrington - - - - - - - 466

Fairbanks, Harold W. The Geology of San Francisco Peninsula - - - 63
Fairchild, H. L. Shore Lines of Lake Warren and of a Lower Water Level in Western New York. (Abstract) - - - - - - - - 106
Farrington, O. C. Average Specific Gravity of Meteorites - - - - 126
The Eruptive Rocks of Mexico - - - - - - - - - 466
Review: Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis. Geo. J. Brush - - - - - - - - 86
Faults, The Measurement of. J. Edward Spurr - - - - - - - 723
Florida. The Elevated Reef of Alexander Agassiz, with Notes on the Geology of Southern Florida. Leon S. Griswold. Review by J. E. Woodman 312
Forestian Stage, Lower - - - - - - - - - - - - - 115
Upper - - - - - - - - - - - - - - - - 116
Former Extension of Cornell Glacier near the Southern End of Melville Bay. R. S. Tarr. Review by T C. Chamberlin - - - - - 203

PAGE

Former Extension of the Appalachian across Mississippi, Louisiana, and Texas. J. C. Branner. Reviewed by A. H. Purdue. - - - - - - 759

Fossil, Lists of pages. 2, 6, 7, 9, 151, 153, 155, 157, 158, 159, 160, 161, 163, 164, 165, 166, 167, 261, 262, 589, 596, 597, 598, 603, 606, 617, 618, 626, 627, 628, 629, 630, 631, 632, 769, 770, 772, 813, 816.

Geikie's Classification of the North European Glacial Deposits. K. Keilhack 113

Geikie, James. The Last Great Baltic Glacier - - - - - - - - 325

Geikie, Sir Archibald. Ancient Volcanoes of Great Britain. Review by J. B. Iddings - - - - - - - - - - - - - - 531

Geography and Geology. Israel C. Russel. Review by T. C. Chamberlin - 302

Geological Commission of the Colony of the Cape of Good Hope. First Report of the. Review by T. C. Chamberlin - - - - - - 647

Geological Relations of the Martinez Group of California at the Typical Locality. John C. Merriam - - - - - - - - - - 767

Geological Society of America, Meeting of. Editorial. J. P. I. - - - 77

Geological Society of America, Meetings of. Editorial. T. C. C. - - 195

Geological Society of America, Papers read before. (See Abstracts)

Geological Survey, Iowa. S. Calvin. Review by T. C. Chamberlin - - 642

Geological Survey of Alabama. E. A. Smith. Report on the Coosa Valley. H. McCally. Review by T. C. Chamberlin - - - - - - 646

Geological Survey of Canada, Annual Report. S. M. Dawson. Review by T. C. Chamberlin - - - - - - - - - - - - - 641

Geology and Natural Resources of Indiana, Twenty-first Annual Report. W. S. Blatchley. Review by T. C. Chamberlin - - - - - - 644

Geology, An Introduction to. W. B. Scott. Review by R. D. Salisbury - 398

Geology, Elementary. R. S. Tarr. Review by H. B. Kümmel - - - 317

Geology of Mexico, a Sketch of. H. Foster Bain - - - - - - - 384

Geology of San Francisco Peninsula. Andrew C. Lawson - - - - 173

Geology of San Francisco Peninsula. Harold W. Fairbanks - - - - 63

Geology of Santa Catalina Island. William Sidney Tangier Smith. Review by F. L. Ransome - - - - - - - - - - - - 208

Geology on Southwestern New England, Note on. Wm. H. Hobbs - - 175

Gilbert, G. K. Old Tracks of Erian Drainage in Western New York. (Abstract) - - - - - - - - - - - - - - 109

Glacial Deposits, Geikie's Classification of the North European. K. Keilhack 113

Glacial Lake Agassiz. Warren Upham. Review by T. C. Chamberlin - - 851

Glacial Observations in the Umanak District Greenland. D. H. Barton. Review by T. C. Chamberlin - - - - - - - - - - 650

Glacial Studies in Greenland. X. T. C. Chamberlin - - - - - - 229

Glacier Bay and its Glaciers. Harry Fielding Reid. Review by I. C. Russell 253

Glaciers of North America. A Reading Lesson for Students in Geography and Geology. Israel C. Russell - - - - - - - - - - 302

Glaciers of North America. I. C. Russell. Review by T. C. Chamberlin - 301

Glaciers, Variations of. Harry Fielding Reid - - - - - - - - 378

Glacier, the Last Great Baltic. James Geikie - - - - - - - - 325

PAGE

Gordon C. H. Review: Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan. F. B. Taylor - - - - - 313
Granitic Intrusions upon the Development of Crystalline Schists; Some Recent Papers on the Influence of. Review by Frank D. Adams - - - 293
Grant, U. S. Review: Preliminary Report on the Marquette District. C. R. Van Hise and W. S. Bayley. With a Chapter on the Republic Trough. H. L. Smyth - - - - - - - - - - - - - - 402
Greenland, Glacial Studies in. X. T. C. Chamberlin - - - - - - 229
Greenland, Glacial Observation on the Umanak District. G. H. Barton. Review by T. C. Chamberlin - - - - - - - - - - 650
Greenland Glaciation, Limit of. Editorial. T. C. C. - - - - - - 81
Grimsley, G. P. Origin and Age of the Gypsum Deposits of Kansas. (Abstract) 94

Hall C. W. Bulletin Minnesota Academy Sciences. Review by T. C. Chamberlin - - - - - - - - - - - - - - - 648
Harris, G. D. Bulletin of American Palæontology. Review by Stuart Weller 309
Harris, G. F. Catalogue of Tertiary Mollusca. Review by W. B. Clark - 853
Harris, G. F. Science of Brickmaking. Review by W. B. Clark - - - - 859
Haworth, E. University Geological Survey of Kansas. Review by Stuart Weller - - - - - - - - - - - - - - 400
Hayes, C. W. Solution of Silica - - - - - - - - - - - - 819
Hayes, C. W., A. H. Brooks and. Crystalline and Metamorphic Rocks of Northwestern Georgia - - - - - - - - - - - - 319
Helvetian Stage - - - - - - - - - - - - - - - - 114
Hershey, Oscar H. Mode of Formation of Till as Illustrated by the Kansas Drift of Northern Illinois - - - - - - - - - - - 50
Hobbs, William H. Note on the Geology of Southwestern New England - 175
Holmes, W. H. Stone Implements of the Potomac, Chesapeake, Tide-water Province. Review by T. C. Chamberlin - - - - - - - - 649
Hopkins, T. C. and C. E. Siebenthal. The Bedford Oölitic Limestone of Indiana. Review by J. C. Branner - - - - - - - - - 529
Hypotheses Bearing on Climate Changes, a Group of. T. C. Chamberlin - 653

Iddings — Editorials:
Meeting of the Geological Society of America - - - - - - 77
International Congress at St. Petersburg - - - - - - - 290
International Congress upon Classification - - - - - - - 848
Rohn's Collections of Rock Specimens - - - - - - - - 195
Seventh Session of the International Congress of Geologists - - - 752
The George Huntington Williams Memorial Lectures - - - - 391
Reviews: Ancient Volcanoes of Great Britain. Archibald Geike - - 531
Ancient Volcanic Rocks of South Montana, Pennsylvania. Florence Bascom - - - - - - - - - - - - - - - 213
Illinois, Correlation of the Devonian Faunas in Southern. Stuart Weller - 625
Illinois, Mode of Formation of Till, as Illustrated by the Kansas Drift of Northern. Oscar H. Hershey - - - - - - - - - - 50

PAGE

Indiana, Geology and Natural Resources Twenty-first Annual Report. W. S. Blatchley. Review by T. C. Chamberlin - - - - - - - - 644
Iowa Geological Survey Report on Lead, Zinc, Artesian Wells, etc. S. Calvin. Review by T. C. Chamberlin - - - - - - - - 648
Introduction to Geology. W. B. Scott. Review by R. D. Salisbury - - 298
Italian Petrological Sketches. III. The Bracciano Cerverteri and Tolfa Regions. Henry S. Washington - - - - - - - - 34
Italian Petrological Studies. IV. The Rocca Monfina Region. Henry S. Washington - - - - - - - - - - - - 241
Italian Petrological Sketches. V. Summary and Conclusion. Henry S. Washington - - - - - - - - - - - - - 349
Iwasaki, C. Andenorite in Japan - - - - - - - - - - 821

James, Joseph, Notes on the Potsdam and Lower Magnesian Formations of Wisconsin and Minnesota. (Abstract) - - - - - - - 9
Japan, Andendiorite in. Iwasaki - - - - - - - - - - 821
Jurassic Rocks in Southwestern Texas, Discovery of. W. F. Cragin - - 813

Kansas and Nebraska, Comparison of the Carboniferous and Permian Formations of. Charles S. Prosser. Pt. I - - - - - - - - 1
Pt. II - - - - - - - - - - - - - - 148
Kansas, University Geological Survey of. E. Haworth. Review by Stuart Weller - - - - - - - - - - - - - - 400
Katzer, F. Devonian Fauna of the Reo Maecuru - - - - - - - 756
Keilhack, K. Professor Geikie's Classification of the North European Glacial Deposits - - - - - - - - - - - - - - 113
Kemp, J. F. The Leucite Hills of Wyoming. (Abstract) - - - - - 100
The Pre-Cambrian Topography of the Eastern Adirondacks. (Abstract) - 101
Keyes, Charles R. Review: Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware and Virginia - - - - - - - - 310
Physical Nature of the Problem of General Geological Correlation - 110
Knowlton, F. H., T. W. Stanton and. Stratigraphy and Palæontology of the Laramie and Related Formations in Wyoming. (Abstract) - - 102
Kümmel, Henry B. The Newark System of New Jersey - - - - - 541
Kümmel, H. B. Elementary Geology. Review by R. S. Tarr - - - 817

Lane, Alfred C. The Grain of Rocks. (Abstract) - - - - - - 222
Last Great Baltic Glacier. James Geikie - - - - - - - - 325
Laurentide Glacier. Geo. M. Dawson - - - - - - - - - 78
Laws of Mines and Mining in the United States. Review by T. C. Chamberlin - - - - - - - - - - - - - 858
Leucitite - - - - - - - - - - - - 41, 245, 369
Leverett, Frank. Water Resources of Illinois. Review by W. H. Norton - 206
Report of the United States Deep Waterways Commission - - - 758
Loess of the Mississippi Valley, Supplementary Hypotheses Respecting the. T. C. Chamberlin - - - - - - - - - - - - 795

PAGE

Marquette Iron Bearing District of Michigan, Preliminary Report on. C. R. Van Hise and W. S. Bayley. With a Chapter on the Republic Trough. H. L. Smyth. Review by U. S. Grant - - - - 402
Marsh, O. C. Dinosaurs of North America. Review by E. C. Chase - - 87
Martinez Group of California at the Typical Locality, the Geological Relations of. John C. Merriam - - - - - - - - - - 767
Maryland, Delaware and Virginia, Eocene Deposits of the Middle Atlantic Slopes in. Wm. B. Clark. Review by Charles R. Keyes - - 310
Maryland Geological Survey. Vol. I. Review by R. D. Salisbury - - 760
McCally, H. Tennessee Valley Regions. Review by Stuart Weller - - 307
Coosa Valley Regions. Review by T. C. Chamberlin - - - - 646
Measurements of Faults. J. E. Spurr - - - - - - - - - 723
Mechlenbergian Stage - - - - - - - - - - - - 115
Medusae in the Niagara Limestone of Illinois, On the Presence of Problematic. Stuart Weller - - - - - - - - - - - - 744
Merriam, John C. The Geological Relation of the Martinez Group of California at the Typical Locality - - - - - - - - - 767
Merrill, George P. Notes on Rock Weathering. (Abstract) - - - - 98
Meteorites, Average Specific Gravity of. Oliver C. Farrington - - - 126
Mexico, A Sketch of the Geology of. H. Foster Bain - - - - - 384
The Eruptive Rocks of. O. C. Farrington - - - - - 466
Michigan, Preliminary Report on the Iron-bearing District of. C. R. Van Hise and W. S. Bayley, with a Chapter on the Republic Trough. H. L. Smyth. Review by U. S. Grant - - - - - - - - 402
Migration of Divides, A Note on the. W. S. Tangier Smith - - - - 809
Mineralogy, with an Introduction on Blowpipe Analysis. Manual of Determinative. Geo. I. Brush. Review by O. C. Farrington - - - 86
Minnnesota Academy of Natural Sciences, Bulletin of. C. W. Hall. Review by T. C. Chamberlin - - - - - - - - - - 648
Final Report on the Geology of; Palæontology. Review by Stuart Weller - - - - - - - - - - - - 308
Missouri Geological Survey, Vol. XI; Clay Deposits. H. A. Wheeler. Review by H. Foster Bain - - - - - - - - - - - 399
Molecular Velocities - - - - - - - - - - - - 661
Moraines of Recession and their Significance in Glacial Theory. Frank Bursley Taylor - - - - - - - - - - - - 421
Multiple Working Hypotheses, The Method of. T. C. Chamberlin - - 837

Nebraska, Comparison of the Carboniferous and Permian Formations of Kansas and. Charles S. Prosser. Pt. I, - - - - - - - - 1
Pt. II - - - - - - - - - - - - - - 148
Nebular Hypothesis - - - - - - - - - - - - - 657
Neudeckian Stage - - - - - - - - - - - - - 115
Newark System of New Jersey Henry B. Kümmel - - - - - - 541
New England, Note on the Geology of Southwestern. William H. Hobbs - - - - - - - - - - - - - 175

PAGE

New Hampshire, Studies on the So-called Porphyritic Gneiss of. R. A. Daly.
Pt. I - - - - - - - - - - - - - - - 654
Pt. II - - - - - - - - - - - - - - - 776
New Jersey, The Newark System of. Henry B. Kümmel - - - - - 541
Niagara Limestone of Northern Illinois, On the Presence of Problematic Medusae in the. Stuart Weller - - - - - - - - - 744
North Carolina and its Resources. Review by T. C. Chamberlin - - - 648
Norton, W. H. Review: Water Resources of Illinois. Frank Leverett - 206

Oölitic Limestone of Indiana, The Bedford. T. C. Hopkins and C. E. Siebenthal. Review by J. C. Branner - - - - - - - - - 529

Palæontology and Phylogeny, Comparative Study of. J. P. Smith - - 507
Bulletin American, Vol. I. G. D. Harris. Review by Stuart Weller - 309
Final Report on the Geology of Minnesota; Vol. III, Pt. II. Review by Stuart Weller - - - - - - - - - - - - 308
Parabolic Velocities - - - - - - - - - - - 659, 660, 661
Penrose, R. A. F., Whitman Cross and. Geology and Mining Industry of the Cripple Creek District. Review by Arthur Winslow - - - 197
Permian Formations of Kansas and Nebraska, Comparison of the Carboniferous and. Pt. I - - - - - - - - - - - - - 1
Pt. II - - - - - - - - - - - - - - 148
Phylogeny, Comparative Study of Palæontology and. J. P. Smith - - 507
Pirsson, L. V., W. H. Weed and, Geology of the Castle Mountain Mining District. Review by H. F. Bain - - - - - - - - - 210
Polandian Stage - - - - - - - - - - - - - - 114
Porphyritic Gneiss of New Hampshire, Studies on the So-called. R. A. Daly,
Pt. I - - - - - - - - - - - - - - - 695
Pt. II - - - - - - - - - - - - - - - 776
Post-Pleistocene Elevation of the Inyo Range and the Lake Beds of Waucobi Embayment, Inyo County, California. Charles D. Walcott - - 340
Potomac Group in Maryland, the Stratigraphy of the. W. B. Clark and Arthur Bibbins - - - - - - - - - - - - - 479
Proceedings of the Davenport Academy of Natural Sciences. Review by T. C. Chamberlin - - - - - - - - - - - - - 648
Proceedings of the Iowa Academy of Sciences. Review by T. C. Chamberlin - - - - - - - - - - - - - - 649
Prosser, Charles S. Comparison of the Carboniferous and Permian Formations of Kansas and Nebraska, Pt. I - - - - - - - - - 1
Pt. II - - - - - - - - - - - - - - 148
Purdue, A. E. Review: The Former Extension of the Appalachians Across Mississippi, Louisiana and Texas. J. C. Branner - - - - 759

Ransome, F. L. Review: The Geology of Santa Catalina Island. Wm. Sidney Tangier Smith - - - - - - - - - - - - - 208
Recent Publications - - - - - - - - - 224, 419, 535, 761

PAGE

Reef of Florida, The Elevated. Alexander Agassiz. With Notes on the Geology of Southern Florida, by Leon S. Griswold. Review by J. Edmund Woodman - - - - - - - - - - - - 312
Report of the United States Deep Waterways Commission. Review by Frank Leverett - - - - - - - - - - - - - - 758
Reid, Harry Fielding. Variations of Glaciers. II - - - - - - 378
Glacier Bay and its Glaciers. (Review by Israel C. Russell) - - 203
Principal Features of the Geology of Southwestern Washington. (Abstract) - - - - - - - - - - - - - 107

REVIEWS:
Ancient Volcanic Rocks of South Mountain, Pennsylvania. Florence Bascom. (J. P. Iddings) - - - - - - - - - - 213
Ancient Volcanoes of Great Britain. Sir Archibald Geike. (J. P. Iddings) - - - - - - - - - - - - - - 531
An Introduction to Geology. W. B Scott. (R. D. S.) - - - - 398
Bedford Oölitic Limestone of Indiana. T. C. Hopkins and C. E. Siebenthal. (J. C. Branner) - - - - - - - - - - 529
Bulletins of American Palæontology. G. F. Harris. (Stuart Weller) 309
Bulletin of the Minnesota Academy of Natural Sciences, Proceedings and Accompanying Papers, 1892–1894. C. W. Hall. (T. C. C.) - 648
Catalogue of the Tertiary Mollusca. G. F. Harris. (William B. Clark) - - - - - - - - - - - - - - - 853
Correlation of Erie-Huron Beaches, with Outlets and Moraines in Southeastern Michigan. F. B. Taylor. (C. H. Gordon) - - - - - 313
Devonian Fauna of the Reo Maecurú. F. Kaetzer. (J. C. Branner) - 757
Dinosaurs of North America. Othniel Clark Marsh. (E. C. C.) - 87
Elementary Geology. Ralph S. Tarr. (Henry B. Kümmel) - - 317
Elevated Reef of Florida. Alexander Agassiz. (J. Edmund Woodman) 312
Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware and Virginia. Wm. B. Clark. (Charles R. Keyes) - - - - 310
Final Report on the Geology of Minnesota, Palæontology. (Stuart Weller) - - - - - - - - - - - - - - - 308
First Report of the Geological Commission of the Colony of the Cape Good Hope. (T. C. C.) - - - - - - - - - - - 647
Former Extension of the Appalachians Across Mississippi, Louisiana, and Texas. J. C. Branner. (A. H. Purdue) - - - - - - 759
Former Extension of Cornell Glacier near the Southern End of Melville Bay. Ralph S. Tarr. (T. C. C.) - - - - - - - 303
Geology and Mining Industry of the Cripple Creek District, Colorado, Whitman Cross and R. A. F. Penrose, Jr. (Arthur Winslow) - - 197
Geology and Natural Resources of Indiana, Twenty-First Annual Report. W. S. Blatchley. (T. C. C.) - - - - - - - - - - 644
Geology of the Castle Mountain Mining District, Montana. W. H. Weed and L. V. Pirsson. (H. F. Bain) - - - - - - - - - 210
Geology of the Santa Catalina Island. Wm. S. T. Smith. (F. L. Ransome) - - - - - - - - - - - - - - 208

PAGE

REVIEWS:

Geological Survey of Alabama, Report on the Valley Regions. E. A. Smith, Part II. On the Coosa Valley, Henry McCalley. (T. C. C.) - 640
Geological Survey of Canada, Annual Report, Vol VIII, 1895. G. M. Dawson. (T. C. C.) - - - - - - - - - - 641
Glacial Lake Agassiz. Warren Upham (T. C. C.) - - - - 851
Glacial Observations in the Umanak District, Greenland. George H. Barton. (T. C. C.) - - - - - - - - - - 650
Glacier Bay and its Glaciers. Harry Fielding Reid. (Israel C. Russell) 203
Glaciers of North America; a Reading Lesson for Students in Geography and Geology. Israel C. Russell. (T. C. C.) - - - 302
Iowa Geological Survey, Vol. VI, Report on Lead, Zinc, Artesian Wells, etc. Samuel Calvin. (T. C. C.) - - - - - - - 642
Law of Mines and Mining in the United States. (T. C. C.) - - 858
Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis. George J. Brush. (O. C. Farrington) - - - - 86
Maryland Geological Survey. W. B. Clark. (R. D. S.) - - - 760
Missouri Geological Survey. H. A. Wheeler. (H. Foster Bain) - - 399
North Carolina and Its Resources. (T. C. C.) - - - - - - 648
Preliminary Report on the Marquette Iron-Bearing District of Michigan. Charles Richard Van Hise and William Shurley Bayley. With a Chapter on the Republic Trough by Henry Lloyd Smyth. (U. S. Grant) - - - - - - - - - - - - - - 402
Proceedings of the Davenport Academy of Sciences. (T. C. C.) - 649
Proceedings of the Iowa Academy of Sciences, 1896. (T. C. C.) - 648
Report of the United States Deep Waterways Commission. (F. Leverett) 758
Report on the Valley Regions of Alabama (Palæozoic Strata). Part I. On the Tennessee Valley Regions, Henry McCalley. (Stuart Weller) 307
Science of Brickmaking. George F. Harris. (Wm. B. Clark) - - 858
Seventeenth Annual Report of the U. S. Geological Survey. Charles D. Walcott. (T. C. C.) - - - - - - - - - - 651
Some Queries on Rock Differentiation. G. F. Becker. (C. F. Tolman, Jr.) 393
Some Recent Papers on the Influence of Granitic Intrusions upon the Development of Crystalline Schists. (Frank D. Adams) - - - 293
Stone Implements of the Potomac-Chesapeake Tidewater Province. W. H. Holmes. From the Fifteenth Annual Report of the Bureau of Ethnology. (T. C. C.) - - - - - - - - - - 649
Submerged Valleys of the Coast of California, U. S. A., and of Lower California, Mexico. George Davidson. (W. S. Tangier Smith) - 533
Transactions of the American Institute of Mining Engineers. (C. F. Tolman, Jr.) - - - - - - - - - - - - 853
University Geological Survey of Kansas. Erasmus Haworth and Assistants. (S. W.) - - - - - - - - - - - - 400
Unpublished Papers of the Geological Survey of Brazil. (J. C. Branner) 756
Water Resources of Illinois. Frank Leverett. (W. H. Norton) - - 206
Rocca Monfina Region - - - - - - - - - - - 241

PAGE

Russell, I. C. Glaciers of North America. Review by T. C. Chamberlin - 302
Notes on the "Plasticity of Ice." (Abstract) - - - - - 103
Winter Meeting of the Geological Society of America. (Editorial) - 194
Review: Glacier Bay and its Glaciers. Harry Fielding Reid. - - 203
Principal Features of the Geology of Southeastern Washington - - 107

Salisbury, Rollin D., Wallace Walter Atwood and. Drift Phenomena in Wisconsin - - - - - - - - - - - - - - - 131
Salisbury, Rollin D. Reviews: An Introduction to Geology. W. B. Scott - 398
Maryland Geological Survey - - - - - - - - - - 760
San Francisco Peninsula, The Geology of. Andrew C. Lawson - - - 73
San Francisco Peninsula, The Geology of. Harold W. Fairbanks - - - 63
Saxonian Stage - - - - - - - - - - - - - - 114
Scanian Stage - - - - - - - - - - - - - - 113
Science of Brickmaking. George F. Harris. Review by Wm. B. Clark - 858
Scott, W. B. Introduction to Geology. Review by R. D. Salisbury - - 398
Seventeenth Annual Report of the United States Geological Survey. Review by T. C. Chamberlin - - - - - - - - - - 651
Siebenthal, C. E., T. C. Hopkins and. The Bedford Oölitic Limestone of Indiana. Review by J. C. Branner - - - - - - - - 529
Smith, James Perrin. Comparative Study of Palæontology and Phylogeny - 507
Smith, William Sidney Tangier. A note on the Migration of Divides - - 809
Geology of the Santa Catalina Island. Review by F. L. Ransome - 208
Review: Submerged Valleys of the Coast of California and Lower California, G. W. Davidson - - - - - - - - - - 533
Specific Gravity of Meteorites, Average. Oliver C. Farrington - - - 126
Spurr, J. Edward. The Measurement of Faults - - - - - - - 723
Squier, G. H. Studies in the Driftless Region of Wisconsin - - - 825
Stanton, Timothy William. A Comparative Study of the Lower Cretaceous Formations and Faunas of the United States - - - - - - 579
Stanton, T. W., F. H. Knowlton and. Stratigraphy and Palæontology of the Laramie and Related Formations in Wyoming. (Abstract) - - 102
Stone Implements of the Potomac Chesapeake Tidewater Province. W. H. Holmes. Review by T. C. Chamberlin - - - - - - - 649
Stratigraphy of the Potomac Group in Maryland. Wm. B. Clark and Arthur Bibbins - - - - - - - - - - - - - - 479
Studies in the Driftless Region of Wisconsin. G. H. Squier - - - 825
STUDIES FOR STUDENTS:
Comparative Study of Palæontology and Phylogeny. James Perrin Smith 507
Deformation of Rocks. V. C. R. Van Hise - - - - - - - 178
Method of Multiple Working Hypotheses. T. C. Chamberlin - - 837
Studies on the So-called Porphyritic Gneiss of New Hampshire. R. A. Daly.
Part I - - - - - - - - - - - - - - 694
Part II - - - - - - - - - - - - - - 776
Submerged Valleys of the Coast of California and Lower California. George Davidson. Review by W. S. T. Smith - - - - - - - 533

PAGE

Supplementary Hypotheses Respecting the Origin of the Loess of the Mississippi Valley. T. C. Chamberlin - - - - - - - - - 795

SURVEYS:

Geological Survey of Iowa, Vol. VI, Report on Lead, Zinc, Artesian Wells, etc. Samuel Calvin. Review by T. C. Chamberlin - - 642

Geological Survey of Alabama. E. A. Smith. Report on the Coosa Valley H. McCauley. Review by T. C. Chamberlin - - - 646

Geological Survey of Canada, Annual Report. Review by T. C. Chamberlin - - - - - - - - - - - - - - - 641

Geology and Natural Resources of Indiana. Twenty-First Annual Report. W. S. Blatchley. Review by T. C. C. - - - - - - - 644

Maryland Geological Survey. Review by R. D. Salisbury - - - 760

Missouri Geological Survey, Vol. XI, Clay Deposits. H. A. Wheeler. Review by H. Foster Bain - - - - - - - - - 399

United States Geological Survey. Review by T. C. Chamberlin - - 651

University Geological Survey of Kansas. E. Haworth. Review by S. Weller 400

Tarr, R. S. Cornell Glacier, Greenland. (Abstract) - - - - - - 95

Tarr, R. S. Elementary Geology. Review by H. B. Kümmel - - - 317

Former Extension of the Cornell Glacier. Review by T. C. Chamberlin 303

Taylor, F. B. Correlation of Erie-Huron Beaches. Review by C. H. Gordon 313

Moraines of Recession and their Significance in Glacial Theory - - 421

Mattawa River the Outlet of the Nipissing Great Lakes. (Abstract) - 220

Tennessee Valley Regions, Report on the Valley Regions of Alabama, Part I on the. Henry McCalley. Review by Stuart Weller - - - 307

Tertiary Mollusca, Catalogue of the. G. F. Harris. Review by W. B. Clark 863

Texas, Discovery of Marine Jurassic Rocks in Southwestern. F. W. Cragin - 813

Till as Illustrated by the Kansas Drift of Northern Illinois — Mode of Formation of. Oscar H. Hershey - - - - - - - - - - 50

Tolfa Region - - - - - - - - - - - - - - - - 47

Tolman, Cyrus F. Jr. Reviews. Some Queries on Rock Differentiation. G. F. Becker - - - - - - - - - - - - - - - 393

Transactions of the American Institute of Mining Engineers - - - 854

Topography of California. Noah Fields Drake - - - - - - - 563

Toscanite - - - - - - - - - - - - - - - 37, 360

Trachydolorites - - - - - - - - - - - - - - - 350

Trachyte - - - - - - - - - - - - - - - - 203

Transactions of the American Institute of Mining Engineers, Review of, by C. F. Tolman, Jr. - - - - - - - - - - - - - 854

Turbarian, Lower - - - - - - - - - - - - - - 115

Turbarian, Upper - - - - - - - - - - - - - - 116

Turner, H. W. Work of the United States Geological Survey in the Sierra Nevada - - - - - - - - - - - - - - - 105

Umanak District, Greenland, Glacial Observations in. Geo. H. Barton. Review by T. C. Chamberlin - - - - - - - - - 650

PAGE

United States Geological Survey — Seventeenth Annual Report. Review by T. C. Chamberlin - - - - - - - - - - - - - 651
University Geological Survey of Kansas. Erasmus Haworth, Vol. II. Review by Stewart Weller - - - - - - - - - - - - 400
Unpublished Papers of the Geological Survey of Brazil. Review by J. C. Branner - - - - - - - - - - - - - - 756
Upham, Warren. Glacial Lake Agassiz. Review by T. C. Chamberlin - 851
Modified Drift in St. Paul, Minnesota. (Abstract) - - - - 111

Valley Regions of Alabama, Report on, Pt. I, On the Tennessee Regions. Henry McCalley. Review by Stuart Weller - - - - - - 307
Van Hise, C. R. and W. S. Bayley. Preliminary Report on Marquette District. Review by U. S. Grant - - - - - - - - - - 402
Van Hise, C. R. Deformation of Rocks - - - - - - - - - 178
Variations of Glaciers. Harry Fielding Reid. II. - - - - - - 378
Virginia — Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware, and Virginia. Wm. Bullock Clark. Review by Charles R. Keyes - - - - - - - - - - - - - - 300
Volcanoes of Great Britain, The Ancient. Archibald Geikie. Review by J. P. Iddings - - - - - - - - - - - - - - 531
Vulsinite - - - - - - - - - - - - - - - 356

Wabaunsee Formation - - - - - - - - - - - 10, 148, 154
Walcott, Charles D. The Post-Pleistocene Elevation of the Inyo Range and the Lake Beds of the Waucobi Embayment, Inyo County, California 340
Seventeenth Annual Report of the United States Geological Survey. Review by T. C. Chamberlin - - - - - - - - - - 651
Washington, Henry S. Italian Petrological Sketches III, The Bracciano, Cerveteri, and Tolfa Regions - - - - - - - - - 34
Italian Petrological Studies, IV — The Rocca Manfina Region - - 241
Italian Petrological Sketches V — Summary and Conclusions - - 349
Water Resources of Illinois. Frank Leverett. Review by W. H. Norton - 208
Watson Thomas L. Evidences of Recent Elevation of the Southern Coast of Baffin's Land - - - - - - - - - - - - - - 17
Waucobi Embayment, Inyo County, California — The Post-Pleistocene Elevation of the Inyo Range and the Lake Beds. Charles D. Walcott - 340
Weller, Stuart. Correlation of the Devonian Faunas in Southern Illinois - 625
Cryptodiscus, Hall - - - - - - - - - - - - - 803
On the Presence of Problematic Fossil Medusæ in the Niagara Limestone of Northern Illinois - - - - - - - - - - 744
Reviews: Bulletins of American Palæontology, Vol. I. G. D. Harris - 309
Final Report on the Geology of Minnesota — Palæontology, Vol. III, Part II - - - - - - - - - - - - - - 308
Report on the Valley Region of Alabama (Palæozoic Strata), Part I, On the Tennessee Valley Regions. Henry McCalley - - - - 307
University Geological Survey of Kansas. E. Haworth - - - 400

PAGE

Weed, W. H. and L. V. Pirsson, Geology of Castle Mountain Mining District, Montana. Review by H. Foster Bain - - - - - - 210
Wheeler, H. A. Missouri Geological Survey. Review by H. Foster Bain - 399
White, David. Age of the Iowa Coals of Henry County, Missouri. (Abstract) 218
White, I. C. Complete Oil-Well Record in the McDonald Coal Fields. (Abstract) - - - - - - - - - - - - - 103
Willis, Bailey. Preliminary Note on the Pleistocene History of Puget Sound. (Abstract) - - - - - - - - - - - - - 99
Winslow, Arthur. Review. Geology and Mining Industry of the Cripple Creek District, Colorado. Whitman Cross and R. A. F. Penrose, Jr. 197
Wisconsin, Studies in the Driftless Region of. G. H. Squier - - - - 824
Wolff, J. E., and A. H. Brooks. Age of the White Limestone of Sussex County, New Jersey. (Abstract) - - - - - - - - - 322
Woodman, J. E. Review. The Elevated Reef of Florida, Alexander Agassiz. With Notes on the Geology of Southern Florida. Leon S. Griswold 312
Woodworth, J. B. Homology of Joints and Artificial Fractures. (Abstract) 97
Unconformities in Martha's Vineyard and Block Island (Abstract) - 96

UNIVERSITY OF TORONTO